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# China Report

SCIENCE AND TECHNOLOGY

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4 AUGUST 1986

# CHINA REPORT

## SCIENCE AND TECHNOLOGY

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NATIONAL DEVELOPMENTS

ZHANG DENGYI DISCUSSES 'SPARK PLAN'

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENCE OF SCIENCE AND MANAGEMENT OF S&T] in Chinese No 4, May 86 pp 5-7

[Article by correspondent Lu Weiwei [7120 5633 5633]: "A Long-range Plan Stressing Substantial Results"]

[Text] Recently the "spark plan" attracted a great deal of attention from the public. The S&T circle and the comrades related to middle-size and small enterprises and rural enterprises especially showed great interest in the "spark plan." Newspapers and periodicals published articles and talks about the "spark plan."

How can a plan with a target geared to the rural economy to promote "short, medium, and fast" technological items evoke so much of a repercussion in public opinion and in S&T circles? On the eve of the Spring Festival I brought up this question when I visited Zhang Dengyi [1728 4098 5030], director of the Science Policy Research Office of the State S&T Commission.

"Why does the 'spark plan' enjoy immense support?" I came straight to the question in asking Comrade Zhang.

"You asked a good question," Comrade Zhang answered with a well-thought-out plan. "The basic purpose of the state decision about the S&T system reform published last year is to reverse the course of S&T work so that it will serve the economy. In the past year, the 'Decision' has been accepted by more and more S&T workers who have recovered from a state far removed from economic construction. Stressing the economy and meeting the demands of economic development have become new features of S&T work." Thus, the "spark plan" is welcomed by the public. The core of the "spark plan" is applied technology; the purpose is to promote medium-size, small, and rural enterprises and raise the standard of S&T in rural construction to promote the local economy. There is some new wording in the S&T policies and their management. The S&T circle and local workers will all be satisfied." Then Zhang, in an orderly way, explained as follows:

Innovation of Stressing Economy in S&T

For many years the State S&T Commission followed the policy that "economic construction must rely on S&T; S&T work must stress economic construction"

and grasped some medium- and long-term items with strategic significance in the national economy and the people's livelihood. Now the "spark plan" stresses the "short, appropriate and quick" items in S&T having a demonstration and promotional significance to medium-size and small enterprises, especially rural enterprises. It is a strategic ideology with new and profound meanings. What do "short, appropriate, and quick" mean? They mean that the cycle of the commercialization of technological results must be short, they must be applicable to medium-size and small enterprises, and they must be quick in gaining economic results in technological development, which is a policy suited to national conditions. We are a country with 800 million rural people and the development of the rural economy holds the decisive influence in the realization of the grand task of the four modernizations. At present, the structure of the rural economy, along with further rural economic system reform, has changed from single-crop cultivation to multiple-trade-and-professional agriculture, industries, and side occupations. Rural enterprise has grown fast in the past few years and at the end of 1984 the total number of national rural enterprises amounted to 6,060,000. The strength of S&T in these enterprises is very poor; they have few professional S&T personnel and basically the standard is low, energy consumption is high, and the economic results are few. They need S&T urgently. For S&T popularization, rural enterprise is just like a vast ocean. S&T, like a small boat, can roam in this ocean at will. For many years, we have been hoping that S&T would serve to promote the local economy, and there were comrades who did some work in the demonstration and popularization of cultivation and others who advanced some good suggestions in the development of the mountain regions and the shores, yet nothing better has been found. The "spark plan" blazed a new trail. To implement this plan is to deliver to the peasants the urgently needed S&T on which the peasants rely to get rich. For the S&T personnel, they also offer a vast world where their talents can be put to good use. By so doing, both the economy and S&T work will be revitalized and the policy will satisfy both sides.

Zhang said that the "spark plan" has won attention and support from the leaders in the central government. One leader from the central government said: "It is a beneficial undertaking both at present and in the future; it will not work to reform the agricultural structure without promoting rural enterprise without relying on S&T. To combine the two may break a new path to fit the Chinese conditions. Thus it should be taken as a basic policy and adhered to and it will yield unexpected results in the long run."

Correspondingly we too formulated some new regulations about the system of appropriation. In the past, owing to shortcomings in the administrative system, the investment in S&T was gratuitous, with no attention paid to utilization benefit. Some of the funds of the three items in S&T which should have been paid back have not been justly and forcefully recalled. The reform measures of matching investment and paying back are implemented in the "spark plan." The state provides a smaller share of funding and the local government and the enterprise provide a larger share of the funding. The funds, responsibilities, and risks are shared by the three parties of the state, the local government, and the enterprise. Once the technology has acquired economic results, the unit which utilized the funds must repay the state. Development projects conforming to the spirit of the "spark plan"

will receive more support from the state. After gaining some profit, these projects may, according to the situation, repay part of the funds to the state and keep the rest for the local government or the enterprise to continue to develop the "short, appropriate, and quick" projects.

#### New Attempt at Comprehensive Development

The "spark plan" aims at the "short, appropriate, and quick" items. The technological level needed by these items is not necessarily very high, while the emphasis is on applicability. In the past, some S&T departments strove only for a single target and stressed only the advancement of the technology itself; some comrades engaged in development research often paid attention only to the research itself and neglected to make a complete set in technology in order to transfer the results of the research into research for practical productivity, which resulted in the separation of technology from the economy.

Agricultural production is a complicated system interwoven with the natural environment, living organisms, and human society. Therefore, we must proceed with comprehensive research on a large scale with a wide range. For example, capitalization of the initial costs, the difficulty in processing, and the possibility of ecological pollution should all be considered, which requires coordination among different professionals from different disciplines, to form a complete set among different technologies. This feature has been fully realized in the "spark plan." The majority of its technological items are neither "high, precise, and advanced" nor "small, native, and massive" but rather "small, specialized, new, and high," which is small scale, specialized, and modern and has a high economic results. Since the "spark plan" stresses pragmatism, it can not promote only a single technology but a complete set of practical technology. This raises the level of requirements for the S&T departments and the S&T research personnel, who must study technology and in addition do comprehensive research and development aimed at local natural economic conditions and production demand in order to gain better economic and social results.

#### Good Situation for Rural Intellectual Development

Zhang said that along with social and economic progress, the people also put forward the demand for agricultural technology for variety and multi-stratification. For example, when people are neither hungry nor cold, they hope to eat better and be clad better and demand that coarse grain be replaced with fine grain and poor quality with fine quality; there is little farmland left in the well-provided areas where people ask for the development of a courtyard economy; in the mountain regions, we should pay attention to water and soil conservation and return the farmland to forest and orchard; and in general, we hope that we can use a small investment to gain great economic results. The purpose of the "spark plan" is to introduce and develop S&T to put an end to the backwardness of rural S&T. Furthermore, all these goals must be realized by the people.

Zhang said that the oft-mentioned term, the challenge of the world's new technology revolution, means in fact competition for the overall promotion of humane quality of life. The significance of the "spark plan" lies not in the handling of several items but in the fact that through the arrangement of some typical and influential items, talent can be cultivated and the quality of the commodity produced by the peasants can be promoted.

One of the important problems in rural development in our country is that the people's knowledge about science cannot meet the demand for development of a commodity economy. According to incomplete statistics, in our country, we have on the average only 1 agricultural student for every 10,000 agricultural workers, professional agricultural S&T personnel make up less than 0.0004 percent of the rural population, while in the United States, of the labor force engaged in agricultural production, 30 percent are college graduates. In West Germany, there is 1 technical advisor for every 350 agricultural households. Compared with the West Germans, we are far behind.

However, we have a great number of school graduates and more than 10 million high school graduates scattered in this vast world, and moreover, each year 2 and 1/2 million senior high school students will graduate and return to the country. They already have basic scientific knowledge but are not trained in specialized technology. Now, facing the new situation in the rural area where the natural economy is being moved toward a commodity economy, they are eager to try but do not know what to do. The poverty of a country is not determined by the lack of natural resources and capital but by its incompetence in developing and utilizing human resources. The "spark plan" puts forward the idea that while promoting appropriate technology, technology development must be combined with the cultivation of local management cadres and technical personnel to make these people the initiators of rural economic development.

In the past, we suggested a policy of "cultivating talent for the rural areas," which has produced some results but lacks practicality and is not widespread. Now, in the implementation of the "spark plan," technical personnel should take the peasants in hand to teach them the technology and turn S&T into a hand weapon for the peasants. If we can reach the requirements of the "spark plan" to train 100 people in 1 county a year, there will be 200,000 people in the whole country in 1 year. Thus if we do this continuously at every level and in every year, a troop with a considerable number of specialized technical people will emerge. And that is why we say that the "spark plan" means not only technological development but, more importantly, means also the development of rural talent and intelligence.

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CSO: 4008/2111

NATIONAL DEVELOPMENTS

SHANGHAI SCIENTISTS SET UP ADVICE NETWORK

OW290828 Beijing XINHUA in English 0800 GMT 29 Jun 86

[Text] Shanghai, 29 Jun (XINHUA)--More than 600 scientific and technical advice offices have been set up in Shanghai since 1979 to aid modernization and economic growth, a seminar being held here was told. They employ the services of 22,000 scientists and scholars from research institutes, universities, factories and government departments.

The seminar on scientific and technical advice centers in Shanghai began on Friday.

An official from the Shanghai Science and Technology Commission said the service had become an important aid to the city's economy, and over the past few years, the offices had advised on more than 300 research projects of national importance. They have helped with a massive research project, called "China by the Year 2000," to forecast what China will be like by the end of the century. Over the past 3 years, 10,000 scientists have given their views in a set of 72 books. By analyzing how far China is behind developed countries, the authors have proposed policies and other measures to help the country catch up. So far, 60 of the 72 books have been published.

The advice network has helped solve Shanghai's public transport problems. Buses in the crowded city carry 13 million passengers a day, and urban traffic is badly jammed. So advisory offices compiled 50 papers containing proposals for an underground railway, which is now being built.

Shanghai authorities also accepted a proposal to move the city's drinking water source from the lower to the upper reaches of the Huangpu River, which runs through the city. The lower reaches have become polluted by factories. This water project, costing one billion yuan, is expected to be completed next year.

The advisory offices have also offered technical and managerial advice to factories and other businesses, and a survey has indicated that 68 such offices have helped generate 1.9 billion yuan in economic benefits.

Shanghai has also established advisory-service links with foreign countries and United Nations agencies.

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CSO: 4010/64

## NATIONAL DEVELOPMENTS

### REQUIREMENTS OF TECHNOLOGICAL COMMERCIALIZATION DISCUSSED

Tianjin KEXUEXUE YU KEXUE JISHU GUANGLI [SCIENCE OF SCIENCE AND MANAGEMENT OF S&T] in Chinese No 4, May 86 pp 11-12

[Article by Chen Shijun [7115 1102 0193], Tianjin University: "Discussion on Requirements of Technology Commercialization for Colleges and Universities"]

[Text] Along with further technology commercialization, there have emerged many requirements for colleges and universities. Now let's discuss its several principal aspects.

#### I. Establish Idea That Scientific Research in Colleges and Universities Should Directly Serve Economic Construction

To meet the demands of technology commercialization, the responsibilities and functions of colleges and universities must be reconsidered. In the past, one school thought that the starting point and goal of scientific research in colleges and universities were to promote academic standards and that the purpose was to promote the development of certain disciplines; another school thought its basic purpose was, through scientific research, to promote the quality of teaching. In my opinion, neither the former nor the latter has fully reflected its due responsibilities and functions. Under the new situation of the S&T system reform, scientific research in colleges and universities must have responsibilities and functions in three areas: promoting scientific development, raising the standard of teaching, and economic construction being oriented, in a straightforward manner. Here the reason I say "straightforward" is that any time people mention education, they often see or think only of its role of promoting economic construction indirectly, that is, through its work, its effect after the cultivated talent is put into the practical production departments. Besides that, scientific research in colleges and universities not only may but also should use their S&T results and their new knowledge and theories to serve economic construction directly. In recent years, many colleges and universities in our country have used their intellectual superiority, talent resource superiority, and better experimental equipment through contracting assignments, technology consultation, technology service, technology training, and cooperative development with the production units and have solved many technical problems directly for the first front of production, which indicates that there are bright prospects for the colleges and universities to serve economic



construction directly. Tianjin University, under the premise of ensuring normal teaching and the completion of the assignments of the state, fully tapped its latent power and helped the enterprises in technical reform, and in 1983 it contracted 173 technical items from production departments. Among them, in the items which passed the evaluation, there were at least three items whose economic result was worth over 1 million RMB.

The responsibilities and functions of colleges and universities in scientific research, by directly facing economic construction, are not only fulfilling the demands of the state S&T policy but also reflecting the world trend in the development of education in colleges and universities. At present, many countries in the world pay special attention to the establishment of so-called "cities of science," "science parks," "industrial science parks," and "industry-teaching associations." No matter what form they use, they necessarily include universities and take scientific research in the universities as their primary force. This shows in one respect the worldwide change in responsibilities and functions of colleges and universities. Prime Minister Thatcher said, presiding over the dedication of the Warwick University science park: "In history, universities have performed two functions: one is to pass the accumulated knowledge on to the next generation and teach them how to think; the second is to create new theories, throw out new ideas, discover scientific laws, invent new hypotheses, and search for the key to open the doors of the unknown world. However, in the past, universities did not have the responsibility to promote and apply new ideas and new discoveries, which were pushed out of the universities. Now the establishment of the science park will give universities a third assignment, that is, to popularize the discoveries and the creative new ideas developed in the universities in society and industry and add them to the wealth of the whole society."

Education in our country must face the world, the future, and modernization; we must fully realize this change in the responsibilities and functions of university scientific research and take the initiative to carry out this change, break the isolation of university scientific research, get out of the small circle in which university scientific research serves only university teaching, face society, and give universities full play to perform their appropriate functions.

## II. University Scientific Research Must Stress Both Academic Standards and Economic Results

Scientific research personnel in the universities are different from those in the professional research organizations; the majority of them are teachers primarily engaged in teaching. Owing to the habit of the profession, they often stress theory, systems, and completeness of knowledge and are interested in abstract theoretical research. Besides, they are not familiar with practical production; therefore, they often onesidedly think that only theoretical topics with an impact on some discipline are significant and are not interested in more concrete topics which do not necessarily have an impact on a discipline but can serve economic construction directly with higher economic results. Some even think that research for result promotion and application is substandard. This kind of sense of value is realized not



only in the choice of topic but also in the assessment of the results of scientific research. In the universities the standard of a result of scientific research is evaluated primarily by the academic standards and theoretical significance, with its economic results neglected. It is worth pointing out that not only does this situation exist universally among those who are engaged directly in scientific research, but also it influences the sense of value of management personnel in scientific research. Obviously, this thinking and sense of value, which are disadvantageous to the commercialization of S&T research activities in universities must be really overcome. In the assessment of scientific research results, we must insist on the principle of equal importance in academic standards and economic results; in the assessment of academic titles, we must stress not only the number and quality of theses but also the accomplished results in practical work such as in research result promotion, popularization of the new knowledge, the training of the recipients, and new technology consultation and service; and we must formulate a corresponding reward policy and encourage university teachers to pay attention to the promotion and application of scientific research. To change the onesidedness in this problem, we need to formulate a reasonable and practical system of indexing for assessment of S&T results and S&T personnel to avoid subjectivity and doing things as one pleases.

### III. Smash "Pedantry," "Study" Research, Establish Management Standpoint

For scientific research in universities to meet the requirement of technology commercialization, the "pedantic" and "study" style of research must be smashed and the management standpoint must be established including the concepts of customers being first, marketing, competition, economic results, and timeliness.

Since technological results can be treated as commodities, they must be transferred, through exchange, from the owner to the recipient, that is, technical results from universities must be transferred to production departments such as factories or enterprises. To a production enterprise, the technical results bought must meet demand, be quickly digested, and create economic results; otherwise they will not be purchased. Therefore, universities, as sellers of technical results, must consider in technical research how to choose a topic in the beginning, and concerning the nature, scope, material condition, and productivity of the customer, they must think of the customers, stress technical market surveys to master market developments, and pay attention to routine relations with production enterprises. Only by changing the practice and style of "choosing topics blindly, stressing the high, the precise and the advanced, isolated from technical research and not caring who is going to use it" can "marketable" technology commodities be produced continuously.

In general, if we want technical results commercialized, we must develop technology. The majority of topics in technical development are problems that the production departments urgently want solved. Under this condition, it is very likely that several research units will get information about needs from the production department and do the same research at the same time.

since technical development has a shorter cycle and higher possibility of success, research topics are easily repetitive and the competition is keen. For technical results competition, in management, the universities must strengthen their cost accounting in technical research, pay attention to the choice of approach for research and choose possible cheaper available materials, and change the way that has been formulated over several decades in the past that technical research must tackle difficult problems, fill the blanks, and succeed at any cost. The concept of time must be strengthened so that as soon as the result comes out, it should be evaluated, transferred, and sold in time to minimize overstocking and being eliminated through selection and competition.

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## NATIONAL DEVELOPMENTS

### EXPERTS DISCUSS SCIENCE, TECHNOLOGY DEVELOPMENT

OW230938 Beijing XINHUA in English 0749 GMT 23 Jun 86

[Text] Beijing, 23 Jun (XINHUA)--Today's PEOPLE'S DAILY carried articles by scientists discussing their work and the development of China's science and technology to mark the opening of the third national meeting of the Chinese Association for Science and Technology.

Speaking on the work of the association, Qian Xuesen, vice-president, said that the task of China's science and technology development is a very important part of the country's Seventh Five-Year Plan (1986-90).

He said the association should serve the needs of the country's ongoing economic reforms and strengthen the ties between the natural and social sciences.

The 75-year-old expert in aerodynamics also urged the association to promote scientific exchanges and pay attention to the emerging new sciences and technology.

Zhou Guangzhao, a theoretical physicist and vice-president of the Chinese Academy of Sciences, said more channels should be opened to create favorable conditions for scientists and technology experts to apply their achievements to economic construction.

Personnel training is another point Zhou stressed. He said that personnel training may be carried out in various ways including sending people to study abroad.

However, people trained in China should constitute the main force in the country's science and technology development, he said.

Cai Shidong, a researcher at the Physics Institute of the Chinese Academy of Sciences, said that a favorable academic environment should be created. This means a lot, he said, to those engaged in scientific and technological research.

He also called for more attention to be paid to personnel training and the promotion of science and technology publications.

/9604

CSO: 4010/64

4 August 1986

## NATIONAL DEVELOPMENTS

## S&amp;T COMMISSIONS, ASSOCIATIONS TO INVIGORATE LOCAL ECONOMY

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENCE OF SCIENCE AND MANAGEMENT OF S&T] in Chinese No 4, May 86 pp 1

[Extract of Fang Yi's [2455 3015] address at the National S&T Conference, edited by You Siyi [3266 1835 1837]: "S&T Commissions, Associations Should Invigorate Local Economy"]

[Text] 1. Situation in the rural area. This has been explained very clearly in the suggestion about the "Seventh 5-year Plan" from the central government and Document No. 1 of this year. Here I mention only three figures: one is that our country has fed 22 percent of the world's population with 7 percent of the world's arable land; the second is that in the past 5 years, our national agricultural output value has been increasing rapidly with an average annual rate of increase of 10 percent; and the third is that our 1 billion population owns 800 jin of grain per capita, which is close to the world standard. Just with these three figures it is enough to say that the development of the rural areas in our country is the best since the founding of the country, and this achievement has become the focus of world attention. This agricultural success, in the final analysis, should be credited to "policy and science." The economic reform and policy adjustment in the rural areas are very successful and they should be further emphasized and perfected. Besides, there is great potential for the promotion of the rural economy with S&T. At present, the yearning for S&T in the rural areas is increasing day after day, and with the reform going deeper and with the development of commodity production, the yearning will become even sharper. One of the important points in Document No. 1 of this year is to use S&T to promote the rural economy. We must have a sufficient understanding about development in the rural areas, proceed from the natural conditions and the local economic situation to grasp firmly the work of agricultural technology popularization, and fully support the rural enterprises' determination to execute Document No. 1.

2. The vast rural area is a huge world which gives full play to the immeasurable forces of S&T and to the intelligence and wisdom of S&T personnel. More and more people understand the rule that there is "no stability without agriculture, no richness without industry, no circulation without commerce, and no prosperity without ability." By "ability" I mean mainly S&T and the people who have mastered S&T; these are the keys in the promotion of

agriculture, industry, and commerce in the rural areas. Only if the comrades in the S&T commissions and associations do a successful job of promoting the local economy can the vitality of S&T be maintained. Therefore, in serving the local economy, the work of the S&T commission must be strengthened and also the work of the S&T office; we must be united and fight to carry out the grand plan of providing appropriate contributions to the realization of the goal of being comparatively well off before the end of this century.

3. The S&T commission is an adviser to the S&T work of the various levels of party commissions and governments, and its principal obligation is to take care of the overall planning, to organize to tackle key problems, to formulate policies, and to coordinate the management of S&T work. The S&T commission is a mass organization of S&T and an aid to the party and government in the development of S&T. Its principal obligation is to unite and organize the S&T workers and arouse the socialist enthusiasm of these people and to serve the economy and the construction of the two civilizations through the exchange and popularization of S&T.

It is a long-term strategic task to popularize S&T and raise the national standard in the knowledge of science, and all the S&T commissions, S&T associations, and the related departments and groups should bear this responsibility and give their superiority full play. This requires both coordination and a clear division of labor. The S&T commission has formulated the "spark" plan with a specific orientation and specific requirements and it must be well organized and carried out. The principal obligation of the S&T associations is to popularize S&T and assist in the training of S&T personnel.

Personnel cultivation is a key link in the work of local economic promotion. At present, it is still a weak link and we should take measures to make it yield results.

Local S&T commissions and associations at various levels should respect, support, help, and coordinate with each other and unite and struggle to promote the local economy.

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## NATIONAL DEVELOPMENTS

### HAJIF-III PROGRAM FOR NONLINEAR ANALYSIS OF AIRCRAFT STRUCTURES

Beijing GUOJI HANGKONG [INTERNATIONAL AVIATION] in Chinese Apr 86 pp 9-11

[Article by Li Ximing [2621 0823 2494] and Zhang Xuefeng [1728 1331 1496]:  
"Nonlinear Analysis System for Aeronautical Structures--Brief Introduction  
to HAJIF-III"]

[Text] A HAJIF-III program including 80,000 FORTRAN statements for non-linear structural analysis has been developed by the Chinese Aeronautical Establishment (CAE). Five fundamental functional subsystems, the monitor, the finite element analyzer, the data file manager, the preprocessor, and the postprocessor are included. Besides 89 fixed analysis flows designed for linear analysis, thermal stress analysis, and a variety of nonlinear analysis, its 44 function modules provide the possibility for users to form new flows fitting their own problems in hand. In the development of the system, a multiple substructure technique is used. A new device for automatically determining the DoF of the analyzer structure and a new computationally effective self-adaptive mixed solution technique for nonlinear analysis are presented. The user-friendly preprocessor and postprocessor and the abundant element library, material library, load library, and algorithm library make it easy to use not only for large aeronautical structures, shipbuilding, and civil application, but also for research. Seven practical structure applications show that the HAJIF-III is very cost-effective for engineering analysis.

The HAJIF-III is a system for the nonlinear analysis of aeronautical structures that was developed by the leaders of the CAE. The work on developing it began in 1981. In October 1984, the scheduled goals for its development were reached, and, after a year of application, in November 1985, it was authenticated by organizations of the Ministry of Aeronautics Industry.

In the guiding idea behind the development of HAJIF-III, besides that it should meet the demands for the usual design of large program systems, particular stress was put on the following three aspects:

1. When seeking a solution to a problem of linear analysis, under the circumstances of insuring fairly good precision, to strive for fairly good economy.

2. The system must easily link up with the CAD system, so as to become the main analysis software of the CAD system.

3. Strive for a program design in accordance with the methods of software engineering. The HAJIF-III is composed of five parts: control program, dynamic function module, data file management system, preprocessing system, and postprocessing system. The entire system has 89 user-selected fixed flows, 44 function modules, 1,117 subprograms, and nearly 80,000 FORTRAN statements. A brief introduction to the system follows:

#### Problem Solving Scope

The HAJIF-III can make the following structural analyses:

1. Static linear analysis;
2. Thermal stress analysis;
3. Plasto-elasticity analysis;
4. Curve analysis (comprising nonlinear curve, linear curve, and Euler's curve analysis);
5. Large displacement on large deformation analysis; and
6. Plasto-elasticity analysis under circumstances of large displacement.

The objects of the HAJIF-III's computations can be divided into two types:

1. The structure of aeronautical and astronautical vehicles, including rigid frame, truss, various types of thin-walled, axially symmetric bodies, and various types of adapter structures;
2. Other structures, including boat and ship, various types of high-rise buildings, dams, bridges, tunnels, chemical industry containers and pipelines, and other machinery structures.

The HAJIF-III has techniques for analyzing complete structures and many kinds of substructures. Therefore, it is suitable both for analysis of large structures and for small-scale computation in topic research.

#### Element Library

The HAJIF-III now contains more than 20 elements. Among them the greater part are conventional elements of bar, beam, plate, and shell. There are also one-dimensional, two-dimensional, and three-dimensional switchback points and other reference elements. The two types of elements exist side by side, and can be mixed together and used. The elements used for nonlinear analysis are set up as formulas according to T.L. (Total Language Formulated) and U.L. (Updated Language Formulated). The two-dimensional reference elements can

process plane stress membrane elements, plane strain elements, and axially symmetrical elements. The three-dimensional elements of the switchback points can stimulate space arbitrary shape masses. Because it can, through methods of release in degree of freedom, release the dropped beam end's moment of force, it will not be drawn into the transitional beam element. The element library has a standard interface, so it is very convenient for the user to add other necessary elements.

#### Material Library

The HAJIF-III's material library is abundant, and can handle nonlinear problems on various kinds of material. There are four methods of describing the stress-strain curve of material:

1. The Ramberg-Osgood three-parameter equation;
2. The power-series expression that describes segments;
3. The exponential expression; and
4. The test curve description (providing certain test points from the system's quasi-expressions).

The HAJIF-III now contains the following material models:

1. Isotropic linear elastic model;
2. Orthogonal opposite-line elastic model;
3. Isotropic thermoelastic model;
4. Telemechanical hardened model;
5. Directional hardened model;
6. Elasticity-ideal plasticity model; and
7. Isosclerotic model.

All models in the system are independently operated, and there are standard interfaces for them, a feature which provides convenient conditions for revising or for adding or subtracting material models.

#### Load Library

The loads that the user can provide are: 1) concentrated load; 3) distributed load; and 3) quasistatic thermal load.



The system also has an aircraft wing area load computing program for the user's use. In addition, the program has an interface so that the user's load computing program can be linked to it.

#### Algorithm Library

As everyone knows, in nonlinear analysis there are no methods of solution that are effective for various types of nonlinear problems. Based on this situation, the HAJIF-III's algorithm library has been provided with various methods for the solution of nonlinear sets of equations, which the user can select and use. These methods are: straight incremental method, Newton's method, revised Newton's method, accelerated convergent revised Newton's method, quasi-Newton's CBFGS and DFP methods. There are also the linear search technique, the incremental added-load arc length method, and the current stiffness parameter method. All these methods combine to form various methods of solution.

When computing an incremental add-on load, in order to be able to select automatically a method of solution in accordance with the specific property of the structure for which a solution is sought (meaning that the degree of nonlinearity of the structure is calculated by current stiffness parameters), so that the seeking of the solution is most economical, a self-adapting mixed method has been specially designed. Results of using it have been fairly good. In addition, the system possesses the capability of providing the user with an automatically selected optimum load increment. This is very convenient for users who lack experience in nonlinear analysis.

When seeking a solution to a curve problem, the system contains the generalized inverse power method that seeks the minimum characteristic of the original point shift by accelerated convergence.

The system contains multiweighted substructure techniques and static polycondensing techniques. The maximum number of substructure series is 10, and each series is divided into 99 substructures. The substructure technique and the static polycondensing technique are effective methods for lowering the degree of freedom of the substructures.

#### Convergence Processing

For convergence processing the HAJIF-III has the following four methods:

1. Single-point convergence (including zero position shift and given position shift convergence);
2. Master-slave convergence;
4. Generalized position shift multipoint convergence; and
4. Nodal point coordinate convergence.

By using the above four processing methods, the system can process all kinds of boundary conditions that are encountered now.

#### Results Provided by Analysis

Based on the required analytic content, the following results can be provided by this system's analysis:

1. It can provide all the results that a linear analysis program can provide;
2. Thermal stress on the structure;
3. A history of the changes in stress, strain, and position shift caused by a load, and the plasticity boundaries of the structure;
4. Critical stress, critical load, and curve model. If part of the structure is a curve at first and then the overall structure is destroyed, the system can provide the load at the time of overall destruction;
5. If a structure's strength needs to be calibrated and checked, the system can provide the residual strength coefficient.

#### Preprocessing Function

The HAJIF-III's preprocessing subsystem contains more than 20 kinds of functional statements, including repetitive statements, mathematical function statements, and geometrical statements. It can automate the finite element net differentiation and generate or revise data, thereby reducing the user's work in preparing data. It also possesses the function of making the structure drawing. What should be particularly pointed out is that the preprocessing subsystem of this system can read out and change raw data provided by other programs recorded on tape by the user for the HAJIF-III's use. This provides very convenient means for a user to use this system.

The preprocessing subsystem of this system is an independent module. It can be linked to any other finite element analysis system for use by the other system.

#### Postprocessing Function

The HAJIF-III's postprocessing system possesses the functions of tabulating and charting: If data output is needed, it can output them in clearly tabulated form, and can directly bind them into book form, thereby reducing the user's work in extracting data and arranging charts. It can draw a diagram of a structure's external shape so as to be seen from any desired angle, draw a finite element net partition diagram, and draw a structure deformation diagram. It can draw the results of computation into various curves. It can draw curved model axes diagrams and contour line diagrams.

## System Design

The basic idea behind the design of the HAJIF-III program was to make use of software engineering methods; to assimilate the strong points of all types of foreign structure analysis systems; to formulate quality standards and design scope; to get a good grasp of the main links in structure design and algorithm design; to do well the program design and the testing work; and to develop a structure analysis system that is flexible, convenient, dependable, and highly efficient.

The purpose of formulating quality standards was to insure that it is convenient to use, its functions are complete, its structure is dependable, its cost is low, and its safeguarding is easy.

The design scope included quality guarantee standards, engineering terminology standards, software design requirements, program code arrangements, and program testing principles.

The algorithm design was conscientiously made to carry out algorithm analysis, make correct proofs, and choose the optimum algorithm in order to insure that the system is highly efficient and the computing economical. The self-adaptive unit empty load method set forth by this system to determine the nodal points of the finite element net has been shown through use to be simple and reliable.

The system's structure is an hierarchical tree structure with the hierarchies distinct and the functions single and clear.

The interfaces of the element library, material library, algorithm library, and the various processing function modules have been standardized, formalized, and weakened, so as to make it easy to enter new elements, new material types, and new methods.

The system design is a structuralized program design that proceeded from top to bottom and that is gradually refined. The program is easy to read, easy to revise, and easy to safeguard.

All of the interface parts of the computer hardware and the system software are concentrated in a small number of models, and are written in standard FORTRAN statements, making it easy to transplant them to other kinds of machines.

## Application of the System

During the process of developing the system, a comprehensive examination was made of all the elements and function modules and all the analytic flows, in which more than 400 large, medium-sized, and small examination questions were computed. Since the end of 1984, the system has made computations on seven items of four aircraft. This not only solved some problems in aircraft design and engineering practice that urgently needed to be solved, but also further

tested and verified the system's reliability. Thus good economic results have already been obtained. These practical applications showed that structural analysis by this system can provide a basis for rationally distributing the structure, lowering the structure's weight, and reducing the number of some experimental projects. Therefore, this system provides a powerful instrument for model design and topic research, and it will lead to clearer and clearer social and economic results.

The HAJIF-III is now in operation in two 7760 computers. The system's functions will be expanded so that it will be able to seek solutions to problems of dynamic nonlinear responses, fatigue, and fracture mechanics.

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## NATIONAL DEVELOPMENTS

### STATUS OF CHINESE HELICOPTER INDUSTRY OUTLINED

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[Article by Wang Shicun [3769 6684 1317]: "Our Country's Helicopter Enterprise"]

[Text] The development of our country's helicopter enterprise began in the mid-fifties. At that time, based on the state development plan, on the one hand we copied the Soviet Mi-4 helicopter and provided it for domestic use; on the other hand, we began to offer helicopter speciality courses in schools to train technical talents in this field.

After more than 30 years of construction, our country's helicopter enterprise now possesses a definite scale: two manufacturing plants and one research and design institute. In addition, in the Low-Speed Aerodynamics Research and Development Center there is a helicopter aerodynamics research team; in the Test Flight Research Center there is a helicopter test flight team; and in the Nanjing Aeronautical Engineering College there is a helicopter teaching and research section. It may be said that our country's helicopter enterprise, in the scientific, designing, manufacturing, and educational aspects, has been formed into a fairly complete system. However, in technology, for various reasons, a lot of time has been wasted and, in comparison with the world's advanced level, there is a definite gap. Below is a brief introduction to the main units in our country that engage in helicopter research, as well as the general situation of their development.

#### Harbin Aircraft Manufacturing Company

It is one of the key enterprises in our country's aeronautics industry. Established in 1951 and 1952, it has produced about a dozen kinds of aircraft and helicopters of four big types. The company now has 17,000 staff and workers and 2,500 engineers and technicians. It has fairly advanced production equipment, and it possesses a fairly strong capability for development. The company, getting patents from Aerospatiale of France, is now manufacturing the "Dolphin" light helicopter.

The Harbin Aircraft Manufacturing Company is our country's main plant for manufacturing helicopters. In February 1958, in accordance with the blueprints and technical data for the Mi-4 helicopter, which were provided by the Soviet side at that time, it began to make a copy of this helicopter. The first test flight of which took place in December of that year. The code name of this helicopter at that time was "Xuanfeng [Whirlwind]-25." In 1959, after state authentication, it was put into batch production. From this time on, our country's helicopter production technology began gradually to develop.

The "Xuanfeng-25" is a single-rotor helicopter. The diameter of its rotor is 21 meters. The helicopter's takeoff weight is 7,200 kilograms. It has one piston engine (a copy of the Soviet Ash-82), and the engine's rated power is 1,250 kilowatts. In its early stage, the Mi-4 helicopter's blade was a composite structure of metallic tubular beams and wood. In the sixties, the company developed on its own a metallic blade of aluminum alloy with girders carrying a honeycombed back-forged piece. Thus in rotor technology level it caused a generational replacement. Following complete manufacture in China of the copy of the Mi-4 helicopter and the improvement of its blade, the helicopter was named in China the "Zhi-5." The Zhi-5 helicopter has developed into models for passenger transport, rescue, aerial survey, and lifesaving at sea. Up to 1979, when production was stopped, more than 500 had been produced, and they played a very big role in the national economy and in national defense construction.

During the course of producing the Zhi-5, the Harbin Aircraft Manufacturing Company test-built several other helicopter models. Among them a fairly successful one, which was developed in cooperation with another unit, was the Zhi-6 helicopter. The Zhi-6 was developed on the basis of the Zhi-5. It has a redesigned airframe and is fitted with a turboshaft engine. The engine's axial rate is 618 kilowatts, and the aircraft's takeoff weight is 7,600 kilograms. In 1968, the Zhi-6 made its first test flight, and was then put into test-production.

To raise the technological level of our country's helicopters, in October 1980, with the approval of the Chinese and French governments, the China National Aero-Technology Import and Export Corporation signed a contract with Aerospatiale of France and the Turbomeca Corporation for the transfer of the manufacturing rights for the SA 365 N/N1 "Dauphin" [Dolphin] helicopter and its engine, under which the Chinese side would assemble and produce 50 helicopters and 100 engines. The Harbin Aircraft Manufacturing Company became the main helicopter plant, and was responsible for the tasks of producing, assembling and test flight of the helicopter. In China this helicopter was designated the Zhi-9, and at present more than 20 of them have been assembled and produced. All of them have been cosigned to the Civil Aviation Administration of China [CAAC], military units, or the China Maritime Helicopter Company. Through the import of technology, the Harbin Aircraft Manufacturing Company and other relevant factories are now carrying out a series of technological transformations in order as fast as possible to make our country's helicopter manufacturing technology attain the level abroad at the end of the seventies and the beginning of the eighties.

## The China Helicopter Research and Design Institute

This institute, located in Jingde City, Jiangxi Province, was set up in 1968. Its basic task is, in accordance with the state development plan, to undertake the work of helicopter research, design, test, and test flight. The institute now has a little over 1,200 staff and workers, of which nearly 600 are scientists and technicians.

Through about a dozen years of development, the China Helicopter Research and Design Institute has now formed a design group with a certain capability for actual work. In the institute are 16 research offices, whose specialities include overall, aerodynamic, strength, structure, lift, system, and ad hoc research. The institute also has the necessary technical support units. The academic disciplines are complete, and its specialities form a complete set. The institute also has a computing center. The institute possesses a variety of experimental methods and testing equipment. It can carry out static tests on the whole aircraft, dynamic tests of its parts, and fatigue tests; tests of the fuel, operating, electrical, and ad hoc systems; as well as continued tests of the helicopter as a whole.

The institute also possesses a certain capability for test-manufacture and processing. Its test-manufacture factory has more than 400 production workers and auxiliary workers. It has more than 150 metal-cutting machine tools of various kinds that are able to machine equipment for ordinary tests and parts for helicopter tests.

Since the institute was established, it has done work on designing, test-manufacturing, and testing several kinds of helicopters (including the Zhi-6). It is now engaged in research on improving and modifying helicopters. In addition, making use of its own technological superiority in other fields, like the development of a wind-driven generator, it is serving national economic construction.

## Changhe Aircraft Manufacturing Plant

This plant was set up at the same time as the China Helicopter Research and Design Institute, and is also located in Ningde City, Jiangxi Province. It is the main aircraft plant in South China. It has a little over 6,000 staff and workers, of which a little over 700 are technicians. The plant occupies an area of about 2.3 million square meters, and the area of its factory buildings is 130,000 square meters.

After 10-odd years of construction, the plant preliminarily possesses the capability for producing medium-sized helicopters. It has more than 1,000 pieces of universal- and special-purpose equipment, including large cutting machine tools and precision machinery tools. The plant has also set up a central measurement office and a central testing office, which have the equipment to make the various measurements and tests needed in helicopter production.

The Changhe Aircraft Manufacturing Plant has produced the main parts for several kinds of helicopters, such as the rotor blade, the automatic tilter, and the tail propeller; and it has assembled various kinds of helicopters. This institute and the China Helicopter Research and Design Institute, in coordination with several dozen relevant units throughout the country, developed the multi-purpose helicopter--the Zhi-8--which was flown for the first time on 11 December 1985 at Jingdezhen. The Zhi-8 is a large helicopter of a single rotor type with tail blades. Its takeoff weight is 13 tons.

#### Baoding Propeller Manufacturing Plant

This plant is located in Baoding City, Hebei Province. It began to be set up in 1962, and in 1964 it was established and put into production. It has mainly undertaken the design, development, and production of the airscrews on various types of aircraft and the propeller hubs and tail propellers on helicopters. In addition, it produces vanes for various kinds of wind-driven machines.

The Baoding Propeller Plant has 2,600 staff and workers, of which 220 are engineers and technicians. The factory building area is 34,000 square meters. In the plant are propeller production workshops, total assembly workshops, as well as fatigue testing offices and composite material testing offices. It also has design and technical offices.

The plant has more than 350 pieces of equipment of various kinds, and its annual output of various types of propellers is about 1,000. It is now producing flexible propeller hubs and duct tail propellers for the "Dolphin" helicopter imported from Aerospatiale of France.

#### Low-Speed Aerodynamics Research Institute

A research institute under the China Aerodynamics Research and Development Center, it is located in Mianyang Prefecture, Sichuan Province. The institute has a Helicopter Research Office, which specially engages in research on helicopter aerodynamics.

Since it began research work on helicopter aerodynamics in 1967, the focus has been on wind tunnel testing of helicopters. The institute now has two wind tunnels for testing helicopters. One is a conventional flow-type wind tunnel. Its testing section is 4 by 3 meters, and its maximum wind speed is 100 meters per second. It can carry out tests on rotors with a diameter of 2 meters. The other one is a series direct flow-type wind tunnel. Its first testing section is 12 by 16 meters, and has a maximum wind speed of 25 meters per second; the second testing section is 8 by 6 meters with a maximum wind speed of 100 meters per second, and can carry out blow tests on rotors with a diameter of 4 meters.



Through many years of trials and hard work, the institute has developed a set of devices used in 4 by 3 meter wind tunnel tests of helicopter models. They mainly include a 35-kilowatt variable-frequency electric machine rotor drive system and two floating frame balances. Of the latter a rotor balance and a fuselage balance can respectively measure the six aerodynamic weights on the rotor and the fuselage. By making use of these devices, both isolated rotor tests and rotor-fuselage combination tests can be conducted. The institute once used a standard rotor model it had made for a proof and check test. In addition, to coordinate with helicopter model research, it also conducted strength measurement tests that included several kinds of helicopter rotors within the Zhi-6 series.

The helicopter model testing device inside the 8 by 6 wind tunnel is now being used for debugging. It uses an 830-kilowatt direct current electric machine to provide the motive power for the rotor, and a ring strain balance is used as the strength-measuring component.

In addition, the institute has initiated the following research projects: research on methods for measuring the wave angle of rotor models; research on techniques for measuring the moment of force on rotor model hinges; research on testing rotor model flutter; and research on rotor/tunnel wall interference. To compare tests, the institute also computes rotor aerodynamic load and rotor flutter.

#### Flight Testing and Research Center

Located in Xi'an Prefecture, Shaanxi Province, the Flight Testing and Research Center began to be set up in 1959. Its principal task is to be responsible for state design-finalization test flights of new types of aircraft as well as test flights of a research nature.

The center has about 1,000 technicians. It is divided into a research department, a measurement and data processing department, an instrument design and manufacturing department, and a flight department. It also has a factory that makes nonstandard testing devices. Under the research department are 10 research offices, among which there is an aircraft test flight research office that includes a helicopter test flight team.

The Flight Testing and Research Center has more than 40 aircraft of various types. It has a large amount of ground testing facilities, such as a flight simulator, an engine test-run platform, and an ejector seat test platform. In addition, it has a 3,400-meter-long runway.

With regard to helicopter test flights, the test flight team has conducted comprehensive test flights of the Zhi-5 and Zhi-6, that is, it has measured their basic performance, their stability, operability, and maneuverability, as well as their stress. In addition, the test flight team has done a lot of test flight research on helicopters, such as research on the specific aerodynamic properties of helicopters, research on their flying quality, as well as measurement of their vibration.

For many years, while doing test flight research work, the test flight team has initiated applied research on Kalman filtering techniques, and has come up with its own set of data processing methods. Also, it has obtained certain results in research on parameter-distinguishing techniques when a helicopter is in highly turbulent motion, and in the formulation of standards for helicopter flying quality.

### Nanjing Aeronautical Engineering College

It is an institution of higher learning that trains high-level technical talents in aeronautical engineering. Founded in 1952, it is now one of our country's key institutions of higher learning. The college has 10 departments. In the aircraft department there is a helicopter engineering teaching and research section.

The helicopter engineering teaching and research section was set up in 1957. Originally part of Northwest Industrial University, it was moved to Nanjing Aeronautical Engineering College in 1970. After 28 years of building, the teaching and research section now has more than 30 teachers. They engage in teaching and scientific research work in aerodynamics, flight dynamics, and helicopter strength and design.

The main equipment of the helicopter training and research section is a rotor laboratory and a large low-speed wind tunnel that can test helicopters and VTOL [vertical takeoff and landing] aircraft. The wind tunnel is of the series cyclonic flow type. The size of its first testing section is 5.10 by 5.25 meters, and it has a maximum wind speed of 32 meters per second; the second testing section is 3.0 by 2.5 meters, and it has a maximum wind speed of 90 meters per second.

From 1961 to the present, the Nanjing Aeronautical Engineering College has trained more than 600 graduates in helicopter specialities. The great majority of them have been assigned to work in relevant research institutes and factories, as well as in the CAAC and military units. Now, every year 35 to 45 B.A.'s, 4 to 6 M.A.'s, and 1 to 2 Ph.D.'s are trained in the helicopter specialities.

In research on helicopter technology, the Nanjing Aeronautical Engineering College has made the following achievements.

1. Research on rotor aerodynamic load. Based on classical rotor vortex flow theory on tailflow models, it has come up with a method for computing a rotor blade's aerodynamic load and its stress analysis. The computer program for this method has been widely popularized and applied in our country.
2. Design of the Y-2 light helicopter. This was the first helicopter designed by our country on its own. Plans for it began in 1965, and in 1975 the aircraft's first test flight was successful. The Y-2 is a single-rotor light helicopter with three rotor blades. Its rotor diameter is 10 meters. It is fitted with a 260-horsepower piston engine, and its normal takeoff gross weight is 1,555 tons.

3. Development of a composite material rotor blade. To improve the performance of the Y-2 helicopter, the Nanjing Aeronautical Engineering College developed for it our country's first composite material rotor blade, completing the development in 1982.

In addition, some departments that use helicopters, like our country's Air Force and Navy as well as the CAAC, also have some research institutes and repair plants that possess a certain level of helicopter technology.

To promote the flourishing of our country's helicopter enterprise, in October 1984, with the approval of the China Aeronautics Society, the Chinese Helicopter Professional Committee was established. Members of the professional committee not only include technicians of the above-mentioned units, but also technicians of helicopter engine plants as well as technicians of the Air Force, Navy, and CAAC. Its establishment provides good conditions for widespread academic interchange and technical explorations by experts, engineers and technicians of our country's helicopter industry, and the committee plays an important role in developing our country's helicopter enterprise.

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## NATIONAL DEVELOPMENTS

### CHINESE-DEVELOPED GAS TURBINES LISTED

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[Article by Li Huaiddi [2621 2037 1221] and others: "Advances in Development of Chinese-Made Light Gas Turbines"]

[Text] In 1984, the State Machine-Building Industry Commission, the State Science and Technology Commission, and the National Defense Industry Office jointly set up the Gas Turbine Applied Research Work Group, and called on relevant units, besides aeronautics, to use it in development work on gas turbines in the ship and industry domains. The party organizations of the Ministry of Aeronautics Industry actively responded to this call, and made a resolution "to vigorously develop gas turbines, put them in the service of energy resources and communications, and implement the policy of maintaining the military industry while switching to the civilian industry, combining the military and the civilian."

Since that time, research work on the use of gas turbines in industry, on ships, and locomotives has developed from the dispersed "stage of spontaneous development" to the overall planning and arrangement "stage of conscious development." During the Sixth Five-Year Plan period, striking progress was made in this research work.

The light gas turbine is a power device derived from the aircraft engine. Its strong points are that it is small in bulk, it starts up fast, and it does not use cooling water. By using it complete sets of units for various purposes can be formed--generating units, locomotives, and ship power devices--and water pump and compressor units. This light gas turbine carries on the advanced technology of and experience in using aircraft engines. Therefore, its total project investment is less. Besides being able to use light oils (fuel oil and diesel oil) and natural gas as fuel, this light gas turbine can use crude oil, heavy oils, and low calorific value fuels. Thus it provides new approaches for opening up new sources of energy and achieving a cascading utilization of energy services. Since 1976, the Ministry of Aeronautics Industry has developed in succession 13 modified light gas turbine models from 5 kinds of aircraft engines (see Table 1). From the beginning to the end of the Sixth Five-Year Plan period, the Ministry of Aeronautics Industry successfully developed and put into production and use 9 models from 4 kinds (see Table 2); they are now being formed into complete

sets and allocated to every large oil field for use in generating electricity, supplying heat, and pumping gas; to coal mines for extinguishing fires; and to hovercraft and experimental railway locomotives (see Table 3). A unit of them is roughly calculated to have an operating time exceeding 190,000 hours, and a single one's longest operating time reaches 13,400 hours.

The Wojiang [turboprop]-6 (WJ6) aircraft engine produced by the Nanfang Power Machinery Company in Zhuzhou City, Hunan Province, and used on the An-12 and Yun-8 aircraft, has been made into modified models which respectively provide the motive power for portable power stations in oilfields and gas turbine sets for compressors, hovercraft, and experimental railway locomotives. Since it began to be developed and put into production in 1973, 42 of the uniaxial Wojiang 6 Gai [modified] I (WJ6G1) have been produced. Formed into complete sets from the YD-2000 container-type portable power station, it has been successfully used in the Changqing, Renqiu, and Zhongyuan oilfields. A single one is roughly calculated to have an operating time exceeding 10,000 hours. The diaxial Wojiang 6 Gai II (WJ6G2) has been technically authenticated, and the WJ6G2C has been fitted onto the top of the Long March I locomotive and has had a trial operation. In 1985, gratifying progress was made on the Wojiang 6GIV (WJ6G4) locomotive power unit, which is being developed.

There have been more than 20 years of experience in using the Wopen [turbojet] 6 (WP6) aircraft jet engine, which is produced by the Liming Machinery Company in Shenyang City. Work on developing a modified set of these engines began in 1979. In 1983 the Wopen 6 Gai (WP6G) set was put into operation as the adjusted peak electricity generating device for the company's factories. In the same year, this company signed a contract with the Belya Power Station in Daqing Oilfield for a heating and power parallel supply unit fueled by natural gas. In October 1984, the unit was formally put into operation, becoming our country's first heating and power parallel supply unit. By 13 January 1986, this unit was roughly calculated to have been in operation for 8,917 hours, generating 34,76 million kilowatt-hours of electricity and producing 90,351 tons of steam. To insure the regular operation of the unit and for the convenience of the consumers, the business practice of "buying gas, selling electricity, and selling steam" was initiated.

The Wojiang 5 (WJ5) aircraft engine used on the An-24, Yun 7, and Yun 7-100 aircraft is produced by the Harbin Aircraft Engine Manufacturing Plant. In 1979, two generating units equipped with the WJ5G gas turbine, a modified model of the WJ5 engine, were consigned to the Xinjiang Oilfield for its use. In 1984, the YD-1250 portable power station equipped with the modified model was put into use in the Daqing Oilfield. The Wozhou Gai [turboshaft modified] (WZ5G) gas turbine composed of the WJ5 engine and a power turbo-shaft, was successfully trial-manufactured in 1978 by the No 2 Machinery Research Institute of Wuxi City, and was used on the water-pumping unit of the Karamay Oilfield in Xinjiang. In 1985, success was obtained in a test using the DQ-1000 inert gas fire-extinguishing device, which has the WZ5 engine as its main engine, for both working and simulating fire extinguishing at the Pingxiang Coal Mine in Jiangxi.

In December 1984, the Sozhou 6 Gai (WZ6G) water-pumping unit, developed by the Lehe Machinery Plant in Jiangxi, was debugged at the Zhongyuan Oilfield. The WZ6G water-pumping unit uses the RST-6 electronic fuel regulating system, which was developed by the Xi'an Aircraft Engine Accessories Manufacturing Plant. As of now, this unit has been in trial-operation for 2,400 hours, and the amount of water it has pumped exceeds 170,000 cubic meters.

The Woshan [turbofan] 9 (WS9), which is produced by the Xi'an Aircraft Engine Company, is an aircraft engine whose performance in China is currently fairly good. There are three kinds of gas turbines developed and refitted from it (see Table 4). Platform stand performance debugging has been completed on the Woshan 9 Gai I A (WS9G1A) industrial-use gas generator, and it is now being manufactured as a complete set with a power turbine. The Woshan 9 Gai II (WS9G2) gas generator is now undergoing tests.

Development work on our country's gas turbines started a little later than that of foreign countries, and its starting point was also fairly low. For example, unit efficiency is not high, the continuous operating time of gas turbines is not long, and the degree of automation in the operation and control of units is not high. However, in future development, through constant searching for, summing up, and accumulating experiences, greater progress is bound to be made in unit work reliability, function of complete sets, economy, and unit seriation.

#### Tables

Table 1 Light Gas Turbines That Are Modified Versions of Aircraft Engines

Aircraft engine	Gas turbines that are modified versions of aircraft engines	Production unit	Progress status
WJ6	WJ6G1/1A	Nanfang Power Machinery Company, Zhuzhou City, southern Hunan Province	in production and use
	WJ6G2		can be put into production and use
	WJ6G2A/2C		in production and use
	409		in production and use
	WJ6G4		under development
WJ5	WJ5G	Harbin Aircraft Engine Manufacturing Plant	in production and use
	WZ5G		in production and use

[continued on following page]

Table 1 [continued]

WP6	WP6G1	Liming Machinery Company, Shenyang City	in production and use
	WP6G1A		in production and use
WZ6	WZ6G		in production and use
	WS9G1	Xi'an Aircraft Engine Manufacturing Plant	in debugging use
WS9	WS9G2		under development
	WS9G3		under development
			under development

Table 2. Gas Turbines That Are Modified Aeronautical Versions in Finalized-Design Production

Model	Type	Production unit	Power kilowatts	Fuel	Year of design finalization
WZ6G	diaxial	Lehe Machinery Plant	750	natural gas	1985
WJ5G	uniaxial	Harbin Aircraft Engine Manufacturing Plant	1,250	natural gas	1984
WZ5G	diaxial	Wuxi No 2 Machinery Institute	1,140	natural gas, kerosene	1977
WJ6G1	uniaxial	Nanfang Power Company	2,000	diesel oil, natural gas	1977
WJ6G2	diaxial	Nanfang Power Company	2,300	diesel oil	1981
WJ6G2C	diaxial	Nanfang Power Company	2,600	diesel oil	1984
409	diaxial	China Shipping and Industry Gas Turbine Research Development Center, Nanfang Power Company	2,600	diesel oil	1979
WP6G1	diaxial	Liming Machinery Company	4,050	natural gas	1983
WP6G1A	diaxial	Liming Machinery Plant	4,700	natural gas	1984

Table 3. Survey of Application of Gas Turbine Modified Aeronautical Versions

Model Designation	Gas turbine in use	Power kilowatts	Location of use
YD-2000 generating unit	WJ6G1/1A	2,000	Zhongyuan, Nanyang, Renqiu, Changqing, and Karamay oilfields
YD-1250 generating unit	WJ5G	1,250	Daqing Oilfield
3DR5 heating and power supply unit	WP6G1/1A	4,050 4,700	Daqing Oilfield
3DR5 water- pumping unit	WP6G1	4,050 4,700	Daqing Oilfield
WB-75 water- pumping unit	WZ6G	750	Zhongyuan Oilfield
WZ-5G water- pumping unit	WZ5G	1,140	fuel plants, Karamay Oilfield
WZ5G compressor unit	WZ5G	1,140	Zhongyuan Oilfield
DQ-1000 coal mine fire extinguisher	WZ5G		undergoing tests at Pingxiang Coal Mine
Hovercraft power	409	2,600	Navy
locomotive power	WJ6G2C	2,600	in test-generation

Table 4. Three Kinds of Gas Turbines That Use Modified Versions of the WSO Aircraft Engine

Model designation	Power in kilowatts (horsepower)	Use
WS9G1	4,420 (6,000)	industry
WS9G2	9,570 (13,000)	ship, industry
WS9G3	11,040 (15,000)	ship, industry

9727/9738

CSO: 4008/65



## NATIONAL DEVELOPMENTS

### REGULATIONS ON AWARDS FOR TECHNICAL PROGRESS

OW130431 Beijing XINHUA Domestic Service in Chinese 0638 GMT 12 Jun 86

[Text] Beijing, 12 Jun (XINHUA)--Regulations on Awards for Rationalization Proposals and Technological Improvements

(Promulgated by the State Council on 16 March 1982)

(Revised and promulgated by the State Council on 4 June 1986)

#### Chapter I: General Principles

Article 1: These regulations are hereby put forth to promote the development of the national economy by encouraging workers and staff members, to improve their operation and management, and to increase the vitality of their enterprises.

Article 2: In these regulations, rationalization proposals refer to methods and measures for the improvement or perfection of production technology, operation, and management in enterprises and institutions; what is called technological improvement refers to improvements and innovations in machines, equipment, tools, technology, and other aspects.

The scope of the rationalization proposals and technological improvements is:

1. Improvement of the quality of industrial products and projects, improvement of the product mix, improvement and development of the variety of living things, and development of new products;
2. Greater efficiency in using and saving energy as well as raw and semi-finished materials and in making use of natural conditions;
3. Improvements in production technology, experiments, inspection methods, labor protection, environmental protection, safety techniques, medical and public health techniques, material transportation, storage, maintenance techniques, designing, statistics, and computer technology;
4. Improvement of tools, equipment, instruments, and installations; and
5. Popularization of scientific and technological achievements, devising

and application of managerial methods and means to modernize enterprises, and mastery, application, and development of imported technology and equipment.

Article 3: The principle of combining moral encouragement with material rewards shall be implemented toward those who make rationalization proposals and technological improvements.

Article 4: These regulations apply to state enterprises and institutions. Enterprises not owned by the state may give such awards in light of these regulations.

## Chapter II: Award Standards and Methods

Article 5: Rationalization proposals or technological improvements made by workers and staff members (collectively or individually) can be awarded only after they are tested, studied, and applied in practice and have achieved results in the production or work of an enterprise or institution.

Article 6: Awards for adopted rationalization proposals and technological improvements whose economic benefits can be calculated are divided into five classes:

<u>Classes</u>	<u>Value of annual saving or value created</u>	<u>Amount of money award</u>	<u>Honorary award</u>
1.	Over 1 million yuan	2,500 to 4,000 yuan	certificate of merit
2.	Over 500,000 yuan and less than 1 million yuan	1,500 to 2,500 yuan	certificate of merit
3.	Over 100,000 yuan and less than 500,000 yuan	500 to 1,500 yuan	certificate of merit
4.	Over 10,000 yuan and less than 100,000 yuan	300 to 500 yuan	commendation
5.	Less than 10,000 yuan	less than 300 yuan	commendation

Rationalization proposals or technological improvements made by using applied scientific and technological achievements for reference that have achieved remarkable economic results should be awarded one class lower than the original.

What is termed "more than the figure" in this article includes the figure itself, and what is termed "less than the figure" does not include the figure itself.

Article 7: Corresponding classes of awards should be determined, in light of Article 6 of these regulations, for adopted rationalization proposals and technological improvements whose economic benefits cannot be directly calculated. In so doing, consideration should be given to the effects of such rationalization proposals and technological improvements, their complexity, and the scope of their popularization.

Article 8: Units accepting rationalization proposals and technological improvements that have been examined and determined to be kept as reserved technology should present the originators with awards within the amount of monetary award listed in Class 5 in accordance with these regulations; when such reserved technology is put into practical use, it should be awarded according to its economic results. When a monetary award is given after the application of such reserved technology, the amount of the monetary award originally issued should be deducted from the new monetary award.

Article 9: The value of annual savings or the value created by adopting rationalization proposals and technological improvements should be calculated by 12 months as a unit, beginning from the day of adoption; it should be examined and verified by the finance department of the adopting unit.

Article 10: New ideas put forward by engineers, technicians, or administrators after fulfilling their duties--ideas which are directly related to their work and have proven to be effective after being put to use--may be given awards in accordance with these regulations. Awards to factory cadres shall be reported to higher authorities for examination and approval.

Article 11: No proposal shall receive multiple awards. When a rationalization proposal or technological improvement project qualifies for two or more awards, it shall receive the higher award. If a proposal or an improvement project is deemed qualified for a higher award in the course of a reevaluation, it shall receive only the balance of the awards.

Article 12: When a rationalization proposal or a technological improvement project is submitted by a collective, the award it receives shall be distributed rationally among the members of the collective according to each individual's contribution.

### Chapter III: Examination and Management

Article 13: Each enterprise and institution shall set up a committee or group to examine rationalization proposals and technological improvement projects. The administrative department shall be in charge of the committee or group, whose members shall include members of the trade union and relevant departments.

Article 14: Personnel of the relevant office or administrative department of an enterprise or institution shall promptly decide whether a rationalization proposal or technological improvement project shall be adopted.

They shall provide an explanation of their decision, which shall be referred to the relevant organs or personnel in written form, and to the evaluation committee or group, for examination.

Units shall, in accordance with regulations, promptly reward a rationalization proposal or technical improvement project it has adopted. Should a proposal or project not be adopted, they should explain the reason for it to whoever submitted the proposal.

Article 15: The grading of rationalization proposals and technological improvement projects should be examined and approved by the users. For Class 1 and Class 2 awards, the users, after approving them, should report their findings to the higher responsible departments for the record.

Article 16: The cost of financial awards shall be borne by the users. In an enterprise, the money it spends for awards shall be considered as part of the production cost; in an institution, the awards shall be defrayed from operating expenses, or by a percentage of the income it keeps.

Article 17: Rationalization proposals and technological improvement projects which have a relatively high economic value but cannot be used by the respective units shall be reported to, and handled by, higher responsible departments or provincial, regional, or municipal economic commissions (economic planning commissions). Proposals and projects of considerable economic value may be sold on the technological market.

Article 18: When a proposal or project for improving efficiency or reducing resources consumption is put into effect, the original quotas may continue to be maintained for a period of 6 to 12 months.

#### Chapter IV: Supervision and Settlement of Disputes

Article 19: The trade union and workers' congress of an enterprise or institution shall have the authority to supervise how these regulations are implemented. They may also ask the relevant departments for information about how the proposals have been handled, implemented, and awarded.

Article 20: The higher responsible departments shall supervise and examine how their subordinate units handle rationalization proposals and technological improvement projects; they shall be responsible for mediating in evaluation-related disputes in their affiliated enterprises and institutions.

Article 21: As for personnel who have won honors by means of deception, the unit that has meted out the award should retract the honors as well as the award. If the case is serious, it should also mete out disciplinary sanctions and investigate economic responsibilities.

Chapter V: Supplementary Articles

Article 22: The State Economic Commission shall be responsible for explaining these regulations.

Article 23: The State Economic Commission shall draw up detailed rules for implementation on the basis of these regulations. All enterprises and institutions shall draw up specific measures for implementation on the basis of these regulations and detailed rules, and report them to the higher responsible departments for the record.

Article 24: These regulations shall become effective upon their promulgation.

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CSO: 4010/64

NATIONAL DEVELOPMENTS

YOUTHS ENCOURAGED TO LEARN SCIENCE, TECHNOLOGY

OW250339 Beijing XINHUA in English 0105 GMT 25 Jun 86

[Text] Beijing, 25 Jun (XINHUA)--Fifteen of the 23 science and technology centers for youngsters, jointly built by the United Nation's Children's Fund (UNICEF) and the China Science and Technology Association, have been completed and put into use.

Meanwhile, three large-scale computer research centers are now underway in three Chinese cities--Hangzhou, Suzhou, and Qingdao.

Zhang Taichang, an official of the China Science and Technology Association said that these projects, which have the functions of training, service, research and demonstration, will provide 300 million Chinese youngsters with springboards for scientific and technological activities.

He said that the Chinese Government has been putting more emphasis on the promotion of science and technology among youngsters in recent years. The China Science and Technology Association has organized various extra-curricular activities to enrich the knowledge of primary and secondary school students.

Zhang Taichang of the association, who is in charge of the juvenile affairs, said that since 1982, about 4 million youngsters have participated in various scientific and technological activities organized by the association. Among them, 400,000 school students have learned to operate computers. At present, there are some 50,000 computers in use in primary and secondary schools, he said.

"Summer camps have not only broadened the horizons of the youngsters, but also created an ideal environment for their spare-time practice," he said.

According to Zhang, the association plans to organize 44 summer camps this year, with 45,000 youngsters participating. They have also invited Hong Kong and Japanese children to take part in these activities.

The Instructors' Association of Science and Technology for Young Pupils was established in 1981. The association now boasts a total of 400,000 members. Meanwhile, local governments have organized a number of scientific and technological groups in schools. In Shanghai alone, there are 3,131 such groups, with 115,000 participants.

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NATIONAL DEVELOPMENTS

SCIENTISTS BACK '100 SCHOOLS' POLICY IN ACADEMICS

OW271719 Beijing XINHUA in English 1514 GMT 27 Jun 86

[Text] Beijing, 27 Jun (XINHUA)--Two thousand leading scientists put their weight today behind the policy of allowing more freedom of ideas in the academic world.

The third national congress of the Chinese Association for Science and Technology, which ended here today, approved a resolution which called for the adoption of the policy of "letting 100 schools of thought contend" into the association's constitution.

The resolution also stressed the principle: "Economic development depends on the advancement of science and technology, and science and technology must serve economic development."

The association has agreed to report the views and demands of scientists and technicians to the Communist Party and government, and to defend their legitimate rights.

A work report by outgoing Association President Zhou Peiyuan was also approved at the meeting.

Newly-elected President Qian Xuesen said: "This meeting has developed democracy and strengthened unity among scientists and technicians."

Qian said Chinese scientific and technical workers were now mobilized to take part in the nationwide reforms, and to make great contributions to the country.

Government and party leaders attending today's closing session included Hu Qili, Fang Yi, Li Peng, Hu Qiaomu, Zhang Jinfu and Song Jian.

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CSO: 4010/64

## NATIONAL DEVELOPMENTS

### EFFECT OF ALLOCATION REFORMS ON COLLEGES DISCUSSED

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENCE OF SCIENCE AND MANAGEMENT OF S&T] in Chinese No 4, May 86 pp 8-10

[Article by Li Renhe [2621 0088 0735], and Tang Zhanqiu [3282 1455 3808] of the State Education Commission Science and Technology Office, and Cai Liyi [5591 4409 5030] of the Zhongshan University Scientific Research Office, and Que Weiming [7067 4850 2494] of the Jinan University Scientific Research Office: "The Effect of Reform of the Allocation System on Institutions of Higher Education"]

[Text] The S&T allocation reform is one of the pivots in the S&T system reform. "The Decision of the CPC Central Committee on S&T Reform," directed against the drawbacks of the S&T allocation system in the past, put forward a series of reform measures. The content of this document can be summarized in three aspects: 1) according to the characteristics of the different kinds of S&T activities, and methods such as public bidding, contracting, self-responsibility, funding and risk investment are to be adopted to implement classified management to provide reasonable financial resources for the different kinds of research; 2) longitudinal control is to be reduced, lateral relations are to be mediated and strengthened and the pressure and vitality of the S&T units for economic construction are to be increased to integrate S&T further with economic construction; 3) competitive allocation is to be implemented, S&T funding is to be linked up with the undertaken task, and the "iron ricebowl" is to be smashed. The implementation of this kind of reform is sure to have a profound and lasting impact on S&T undertakings in our country and in economic and social development, and it will promote education greatly.

#### I. Importance of Allocation System Reform

##### 1. Spurring a Tighter Combination Between S&T and Economic Construction

In October 1982, Premier Zhao Ziyang initiated the strategic policy that economic vitalization must rely on S&T and S&T must be geared to economic construction. This national policy has had a great effect on the tighter combination of S&T with the economy. For a variety of reasons, the tendency toward disjunction between S&T and economic construction in our country has not been essentially reversed. In the enterprises, especially the large and



medium-size key enterprises, their desire to rely on S&T is not strong enough; even if some enterprises wish to rely on S&T, owing to the lack of capital to adopt some new technology or new products, often their ability falls short of their wishes. The S&T research units acquire their funding mainly from their superior departments and they can get by without being geared to the economy. Thus they too lack the vitality and pressure created by facing the economy.

The "Decision of the Central Committee of the Communist Party of China on S&T System Reform" was put forward to implement the system of combining a planned economy with market adjustment to let the enterprises make their own decisions and join in market competition. This will certainly and greatly increase the demand of the production units on S&T, thus increasing the momentum and pressure of the enterprises relying on S&T. The decision of S&T system reform also stipulates that the enterprises may distribute their technology development funds to the costs by stages and may apply to banks for technology development loans; in case of special need, the enterprise may draw an appropriate amount of money from their profits prior to taxation for their technology development fund, thus provides new channels of funding for enterprises relying on S&T. In an S&T organization, after the allocation system reform, the technology contract system will be implemented, step by step, in technology development work and application research which may gain some practical value in the short term. The research organizations engaged in this aspect will reduce, step by step, the operational funds appropriated by the state; requiring that, within 3 to 5 years, the majority will be able to support themselves with operational funds, thus forcing the S&T organizations of this kind to face the economy. Otherwise, they will not be able to survive, thus increasing the pressure on them. Therefore, after the economic reforms and the allocation system reform, it is possible for the enterprise to rely on the S&T fund, use economic measures, and spur their S&T research units to face economic construction. The S&T research units must also turn to the economy to solve the S&T problems for the enterprise in order to get funding for research and development, which will be an important source of S&T and economic construction can be closely combined, thus solving the problems of "targeting" and "relying on."

## 2. Spurring Reasonable Deployment in Various Research Activities

A reasonable proportional development among basic research, applications research, and technology development is an important guarantee to make S&T operate effectively on the economy and maintain this kind of effect, and it is also the important content of a state policy on S&T. In the past, owing to the lack of practical and effective measures, the structure of several kinds of research in our country has been maladjusted for a long time.

Those in charge of the S&T allocation system reform have decided to deploy classified guidance to different types of research. Technology development and applications research which may gain practical results in the short term are adjusted by the technology market and are transferred to become productive. Important S&T research listed in the state and local government plans, development projects, key laboratories, construction of test sites, public

utility research and S&T services, and fundamental technical work are allocated by the state. Advanced technology development with rapid change and high risk, and investments to start businesses, are allocated or granted as loans for control and adjustment to stimulate their growth. Basic research and part of the application research (i.e., retained for future use) are subsidized by the state science foundation to ensure their stable and continuous development. This kind of fund control adjusts not only technology development and practical short-term research but also other kinds of research activities. As long as we continue to analyze the effect of the funds actually being put in on economic construction and S&T development and practical short-term research but also other kinds of research activities. As long as we continue to analyze the effect of the funds actually being put in on economic construction and S&T development, and draw on the experience of other countries, an S&T structure conforming to the reality of our country and to modernization construction may be established gradually.

### 3. Ending the Separation of the Five Front Armies and Departmental and Local Ownership

After the founding of the country, our government assembled the S&T forces, organized and established the huge national and provincial academies of sciences and the S&T research system of national defense and military engineering. Thus there emerged a S&T troop including the five systems of the Chinese Academy of Sciences, the industrial departments in the central government, the industrial departments in local governments, national defense, and military engineering, and colleges and universities. These systems have during a certain period of time played a positive role on some urgent tasks for the state. However, viewing the five systems as a whole, each did things its own way and had a style of its own, thus resulting in serious dispersion and redundancy in the establishment of the S&T mechanism and research items. It is difficult to coordinate and is disjointed from the economic structure; the state allocated funds according to administrative jurisdiction and each department and local government managed according to the departmental and local systems of ownership, resulting in discouraging the enthusiasm of some of the S&T personnel.

This drawback was long since spotted by the various authorities. After the 3d Plenum of 11th Party Central Committee, the state Science Commission tried to adjust the deployment of the S&T research mechanism in our country but owing to departmental and local ownership, the results were very few and it became a chronic and stubborn disease in the S&T system of our country.

Scientific research institutions are academic research units and they hope to have true autonomy in academic research while one of the things that greatly affects the autonomy of academic research is funding control from the top. The S&T allocation system reform has changed the relationship between the S&T research units and their superior authorities and they can break the bond of the five sources and departmental and local ownership in order to be more autonomous in being geared to face society.

#### 4. Effectively Spurring Internal Reforms in Research Institutes

The allocation system reform has weakened longitudinal control and strengthened latitudinal relationships, expanded the autonomy of the research units, and provided the research units with conditions for reform. The allocation system reform spurs S&T research to face society and join the competition. Thus there can be force and pressure for internal reform.

The competitive allocation system reform smashed the "iron ricebowl" in which the institutes eat from the state and individuals eat from the institutes. Thus it forces the S&T institutes and the S&T personnel to increase their efficiency and improve their professional skills and to gain more and better results to strive for survival and growth in the competition. To survive in the competition, the research institutes and the colleges and universities must change their inappropriate management, organization, and personnel systems; besides, they must adjust the direction of research and targets for a topic and strengthen relations and coordination among the different disciplines within to develop overlapping disciplines. Without reform, the S&T units can hardly survive and only through reform can the various problems which exist in the research units be solved; these problems are disadvantageous to contract work in research. Only then can the enthusiasm for invention and creation by S&T personnel be encouraged, the bond of the original system be broken, and the initiative taken to face the economy.

#### II. Measures To Be Taken by the Universities To Meet the Allocation Reform

##### 1. Replace Inappropriate Old Concepts and Establish New Ones To gear to the Economy.

There is a problem of concept and thought transformation in the higher education system reform. For example, there exist different understandings of the words "schools of higher education should take teaching as their principal mission," "S&T research must serve teaching," "colleges and universities must be both the center of education and the center of S&T research," etc. In S&T research work in the universities, there is in general a shortage of concepts of market, competition, and economic results. In rewarding accomplishments and making job promotions, there exist a grave egalitarianism and a concept of seniority based on years of service.

In our opinion the concept that universities should take teaching as their principal mission is lopsided. To cultivate higher-level specialists and to promote S&T education are the two basic assignments for schools of higher education; scientific research and teaching are both important measures to cultivate high-level specialists. Without high-level scientific research there will be no talent of high quality cultivated. Full utilization of the intellectual resources, the academic environment, and the laboratories of the universities has a profound significance in the promotion of the scientific education and the modernization of construction in our country. Besides, one investment can yield two kinds of interest: technology results and talented people, which are also cost-efficient.

In schools of higher education, the prejudice of despising the work of technology and development is deeply rooted. For example, people engaged in technology work are looked upon as inferior to others and technological inventions are considered "worthless" or "substandard." In the assessment of titles and promotions, technology development usually is not used as a basis, resulting in many people not wanting to engage in technological work or not wanting to be assessed with a S&T title. Therefore, for a long time, in the work of S&T research in the schools, teachers were only satisfied with publishing articles and writing and had little interest in applied research with economic results, were not willing to do development research, had little enthusiasm for promoting the application of new technology or products, and even more were unwilling to go to the factories or enterprises to do S&T development or promote the results. Personnel in the field of technology in the universities are few, their quality is not high, and the structure of the personnel is not reasonable.

Therefore, we must have a correct understanding of the mission of the schools of higher education and change the thought of despising technological work among the leading cadres and the teachers, staff, and workers and establish a strong technology system in the schools and encourage teachers, staff, and workers to solve technological problems of economic construction, especially the problems of high technology. We must establish the general mood of valuing technology and development and strive for economic and social results. In every piece of research work, we should establish the thought of serving economic construction. This spirit should also be adhered to in basic research and applied research; we must pay attention to promoting basic research with future applications and applied research which can promote development ability. We must provide necessary theoretical reserves for economic construction and the S&T growth of our country to ensure the after-effects of economic and S&T growth.

## 2. Start with Reality and Division of Labor, Play Exemplary Role in Different Fields and Levels.

In schools of higher education, especially in the science colleges of universities, scientific researchers should regard basic and applied research as their principal work. To coordinate with the national S&T allocation system reform, research institutes of various levels must be readjusted. Colleges and universities should take the initiative to accept assignments from industrial departments and enterprises, especially large and medium-size key enterprises, and take their solution of important S&T problems in economic construction as the important assignments of their S&T research. Various schools of higher education should be based on the reality of the state and the region and start with the needs of economic construction to select their topics for research. With high-tech, difficult, or labor-intensive items, items requiring coordination with related disciplines, state-run items, items of application and technical development research targeted at economic construction, items for absorption and digestion of introduced technology, applied technology targeted at medium-size and small-enterprises (i.e., "short, appropriate, and quick" technology) and various

kinds of research at different levels of difficulty and with different quality requirements, the schools should choose according to the nature of the school, direction of development, the purpose of the education, and the strength of their research force to take advantage of their own superiorities.

### 3. Stress the Fundamentals and Application, Maintain the Aftereffects of Technology Development.

Universities, while carrying out the policy of gearing to the economy and stressing technology development, should appropriately arrange their basic and applied research. Among the several S&T ranks, universities should share more responsibility for basic research to achieve greater results. Universities have the responsibility to cultivate advanced specialists and their basic research must maintain a certain proportion and continue to develop steadily. Research in the universities in the past did not have clear goals in application, nor any further development with their research results; the related departments and the enterprises paid no attention to the results of the applied research in the universities, therefore, the ratio in technical-results application and the economic results were both low. To alter this situation, universities must aim at the important technological problems of economic construction and the enterprises and use basic theories to guide and promote applied research. Thus technology development in the universities is both built on the foundation of economic construction and able to use basic research as its backing, with a higher starting point, to keep the technology development going on.

### 4. Unite To Join the Competition

To promote strength for competition, universities should unite their strengths, based on the needs of the practical assignments or the trend of development of that discipline, to strengthen lateral relations among the various disciplines and to establish cooperative research groups on certain topics, comprehensive research and development centers and consulting service centers, interdisciplinary S&T cooperative committees, and various cooperative organizations to give full play to the superiority of the universities in their many disciplines. Unite together and do well in the organizing and coordination work, the superiority will manifest itself, and it will be easy to solve the important comprehensive technological problems. So the universities, the disciplines in a university, the universities, the industrial departments, and the enterprises must have connections and be united. Since 1979, in and out of the organization department of the Ministry of Education, the coordination group established by the seven universities has accumulated beneficial experience in contracting the projects of the Shanxi and Nei Monggol remote-sensing technology application and reinforced the concrete multipurpose platform in the Nanhai oil field development. They are the successful examples of cooperation among universities in contracting important assignments of the state.

5. Stress Key Discipline on Establishment of Key Laboratories, Create open Bases of Teaching and S&T Research.

To increase the ability of the research forces in the universities to cultivate specialized talent of high quality, we must step by step and with a plan establish in the universities a group of key disciplines with a reasonable structure of classification. The key disciplines aim at taking the lead as examples in the promotion of the quality of education and academic standards to be able to solve the important S&T problems in economic construction and social development to provide scientific bases for important decision making for the state. These key disciplines are the key bases for laboratory scientific research and talent cultivation. We must strive for support from the related departments of the state and the local governments, raise funds through the different channels such as contracting assignments, technology developments, and management, and strengthen the establishment of laboratories with a plan. Besides, we must establish a strong contingent of laboratories to give full play to the utilization and efficiency of the instruments. We must take the initiative to create conditions for the key laboratories to implement, step by step, opening up to a different extent and to give full play to the positive role of teaching and S&T research within and outside the universities.

The allocation reform will create competition among the universities and the departments in a university and among the research institutes. This competition will spur the universities, departments, and institutes to take the initiative to concentrate their own forces to take effective measures to meet the demands of economic development. Some of the universities will improve step by step and raise their standards, and their proportion of scientific research will increase and they will have a better connection with economic construction to become universities of research in style, which are mainly for scientific research and for cultivating specialized talent of a higher standard.

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PHYSICAL SCIENCES

INTERFACE DEFECTS IN LPE  $\text{Ga}_x\text{In}_{1-x}\text{P}/\text{GaAs}(100)$  OBSERVED

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7  
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[Article by Chen Jie [7115 2638], Fundamental Physics Center, China University of Science and Technology, Liang Jingguo [4731 7234 0948], Yu Lisheng [5713 7787 3932], and Liu Hongxun [0491 1347 8113], Department of Physics, Beijing University: "Observation on the Interface Defects in LPE  $\text{Ga}_x\text{In}_{1-x}\text{P}/\text{GaAs}(100)$  by TEM," received 1 February 1985]

[Text] English Abstract: Plane-section, cross-section, and angle-lapped specimens of LPE  $\text{Ga}_x\text{In}_{1-x}\text{P}/\text{GaAs}$  were prepared. The defects at interface were examined and analyzed by TEM. Burgers vectors of most dislocation lines at interface are  $b = \frac{1}{2}(110)$ . Dislocation lines in plane-section specimens are bent and form dislocation network. Dislocation lines in cross-section specimens are straight and discrete, with no network formed. A new model of dislocation generation in LPE growth  $\text{Ga}_x\text{In}_{1-x}\text{P}$  layers is proposed to account for the dislocation distribution. It is believed that the inclusion introduced during growth is the main source of dislocations in the epitaxial layers. It is concluded from the observation of the angle-lapped specimens that dislocations propagate from substrate into epitaxial layers by bending and surface generation mechanism.

I. Introduction

In recent years,  $\text{Ga}_x\text{In}_{1-x}\text{P}$  has aroused great interest in research on semiconductor photoelectric materials. 300K,  $x = 0.74$ ,  $E_g \approx 2.25\text{eV}$  is one of the materials in current reports which has the broadest direct gap<sup>1</sup>. In the epitaxial growth process, defects of various shapes can be introduced inside the crystal. Experiments show that interface defects have a clear influence on the semiconductor components. The researches of Hutchinson<sup>2</sup>, Woolhouse<sup>3</sup> and others using transmission electron microscopes have proven that the dark lines (DLD) created by heterostructure laser degeneracy are a network of dislocation formed by the dislocation dipole, and are developed and formed by the initial penetration of dislocation in the crystal in the process of being excited by light. Merne<sup>4</sup>, Matthews<sup>5</sup> and Abrahams<sup>6</sup> have studied theoretically, the laws and forms created by mismatch dislocation on epitaxially grown interfaces and analyzed nucleation and growth and the slip and climb mechanisms of mismatch dislocations on interfaces. Booker<sup>7</sup> used an electron microscope to

study the laws and forms generated by dislocation in semiconductor epitaxially grown layers and pointed out the mechanisms which formed mismatch dislocation. This paper uses ultrahigh pressure electron microscope to observe and analyze the characteristics of dislocation distribution in the vicinity of the interface in different specimens and proposes a model of dislocation generation in GaInP liquid epitaxial growth and believes that the primary source of dislocation in epitaxial layers is impurities on the substrate surface and in the mother liquor; we discover that the dislocation in the substrate is expanded outward toward the epitaxial layer by the bending and surface generation mechanism.

## II. Experiment

The experiment specimen was a GaAs/Ga<sub>x</sub>In<sub>1-x</sub>P ( $x = 0.4-0.5$ ) single heterostructure, the epitaxial layer was grown using customary liquid epitaxial technique on a GaAs substrate oriented (100). The substrate thickness was 300  $\mu\text{m}$ , the growth temperature was 777°C, the epitaxial layer thickness was 3-6  $\mu\text{m}$ . Plane-section, cross-section and angle-lapped specimens refers to the specimen observation surface as parallel to, perpendicular to or oblique to the growth interface. We first used mechanical grinding to thin the specimen to 30  $\mu\text{m}$ , then prepared the TEM specimen through hydro-chemical corrosion, the protectant was lanolin, the corrosive was Br<sub>2</sub>-CH<sub>3</sub>OH. The instrument used for observation was a TEM-1000 transmission electron microscope, the accelerated voltage was 1000kV.

## III. Experiment Results and Discussion

In epitaxial growth, the dislocation in the epitaxial layer can be induced by the following ways:

- 1) Expansion of the substrate dislocation; 2) collective growth of impurities in the growth process; 3) coalescence of spot defect to form a dislocation ring; 4) plastic deformation in the growth, cooling, and removal process; 5) mismatch dislocation created by mismatched stress introduced by crystal mismatch.

Figure 1 (see Plate I) is a topographic image of dislocation of the plane-section specimen, the extinction diffraction dingchu [1353 0427] dislocation line Burgers vector  $b = \frac{1}{2}(110)$ . From the figure it can be seen that most of the dislocation lines appear paired, and their interweaving forms a dislocation network. The factors which caused this may be the impurities. Since initially there were some impurities on the growth surface (the substrate surface), after the substrate and the mother liquor came in contact, the places where there were impurities were sites for nucleation first, and in the growth process, the dislocation lines which grew interwove to form a dislocation network. From Figure 1 it can be seen that the dislocation lines are linked to a black dot (A dot), which may be impurities, and thus we feel that this is support for the above described model. The very regularly curved dislocation line of the border in Figure 2 (see Plate I) is not due to the corrosion thinning process nor is it strict parallel growth interface thinning, but is produced at an angle, AB is the epitaxial interface, its may come from



the surface generation mechanism provided by the lower surface. (a) in Figure 3 is the surface generation mechanism, with the action of mismatch stress, dislocation within the epitaxial layer surface nucleates and along with the continuation of the epitaxial process it moves toward the epitaxial layer; (b) is the bending mechanism, the initial penetration dislocation is bent by the stress at the interface, and the result is that there is dislocation at the interface but there is none within the epitaxial layer; (c) is the bending and surface generation mechanism, near the interface the place where the penetration dislocation is exposed a new dislocation is generated due to the action of stress, the dislocation generated and the original dislocation at the interface bend in opposite directions and form two sections, and they continue to expand in the epitaxial layer as epitaxis continues. Figure 4 (Plate I) is the angle-lapped specimen. At the place indicated by the arrow it can clearly be seen that the substrate dislocation is expanding into the epitaxial layer, and one branch, crotch-like becomes two, its forming mechanism is the bending and surface generation mechanism described above<sup>7</sup>. From this it can be seen that the bending and surface generation mechanism is the primary mechanism for the substrate dislocation to expand into the epitaxial layer.

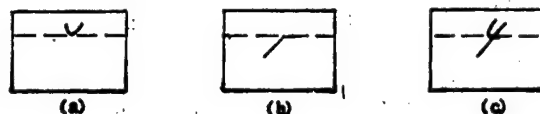


Figure 3. Diagram of Bending and Surface Generation Mechanism

Figure 5 is the cross-section specimen (Plate I). Comparing it with the plane-section specimen, one can see that there is no interwoven dislocation network in the cross-section specimen, the dislocation lines are straight and basically arranged in the same direction. The generation of this type of discrete dislocation line can also be explained by the impurity generation mechanism discussed above. Due to the impurities on the growth surface, after contact with the mother liquor, just as the mother liquor passes over the impurity, due to surface tension action, first of all a single epitaxial layer coagulates on the impurity surface, and in the coagulation process, the impurity surface nucleates to generate a dislocation, and as the epitaxis continues, the dislocation continues to expand. Most of the dislocation lines are arranged in the same direction which indicates that in the epitaxial growth process, the dislocation has a preferred growth direction. In addition, in Figure 5 we can see that the dislocation line is associated with a black dot, which fits with the above described mechanism.

#### IV. Conclusion

Through transmission electron microscope observation of the plane-section, cross-section and angle-lapped specimens and analysis of the characteristics of dislocation distribution in comparable epitaxial layers, we obtain the following conclusions:

- (1) The Burgers vector of the dislocation lines observed was  $b$  averaged  $\frac{1}{2}(110)$ .

(2) Dislocation line in the plane-section specimen bent and interwove to form a dislocation network; the dislocation lines in the cross-section specimen were straight and did not form a network. Analysis recognized that in  $\text{In}_x\text{Ga}_{1-x}\text{P}$  LPE growth, the primary source of dislocations in the epitaxial layer is impurities in the substrate surface and mother liquor, and in the epitaxial process, the dislocations produced because of this continue to expand and propagate and under thermal stress move to form a dislocation network. Therefore, the cleanliness of the substrate surface is of utmost importance in growing epitaxial layers properly and this fits with the results of actual epitaxial growth experiments<sup>9</sup>.

(3) The substrate dislocations observed in the angle-lapped specimen was expanded into the epitaxial layer by bending and surface generation mechanisms, therefore reducing the density of dislocations in the substrate is an important technique for improving epitaxial chip quality.

(4) No mismatch dislocation networks produced by mismatch stress were observed in the epitaxial layer, this means that the crystal lattice of the specimens used was well matched.

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PHYSICAL SCIENCES

MONTE CARLO METHOD USED TO STUDY SENSITIVITY OF  $V_T$  IN SHORT CHANNEL MOSFET

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[Article by Zhao Honglin [6392 7703 7792], Department of Electrical Engineering, Tianjin University: "Monte Carlo Study of Sensitivity of  $V_T$  in Short Channel MOSFET"; received 24 February 1985]

[Text] English Abstract: Monte Carlo method has been used to study the sensitivity of  $V_T$  to  $\text{SiO}_2$  thickness  $t_{\text{ox}}$ , charge density of surface state  $Q_{\text{ss}}$ , substrate impurity density  $N_A$ , channel length  $L$  etc., while the transistor's geometry and process parameters varying practically. The dispersion of  $V_T$  is also studied. Results show that when  $L$  enters short channel region, the sensitivity of  $V_T$  to  $L$  increases rapidly while to  $t_{\text{ox}}$ ,  $Q_{\text{ss}}$ , and  $N_A$  it decreases. The distribution of  $V_T$  is normal.

I. Introduction

Using the Monte Carlo method to carry out component processing simulation can predict, the average values and distribution of output component parameters from the wave range of the input variables of raw materials, dimensions, and processing parameters. Furthermore, in a large number of input variables, it can also distinguish the primary and secondary factors that cause output parameter dispersion<sup>1</sup>.

After a MOSFET's  $L$  drops to a certain value,  $V_T$  is no longer only a function of  $N_A$ ,  $t_{\text{ox}}$ , and  $Q_{\text{ss}}$ , but also is related to  $L$ , channel width  $w$  and the source-drain junction depth  $\gamma_j$ . This paper uses the Monte Carlo method to study the above characteristics.

The sensitivity of the output parameters is a function of an input variable's wave on its dispersion. This work studies the changes in  $V_T$  on the sensitivity of variables when  $L$  is gradually shortened.

II. Simulation Method

After the dimensions of a MOSFET are reduced, the expression of  $V_T$  is<sup>2</sup>:

$$V_T = \phi_{ms} - \frac{Q_{ss}}{C_{ox}} + 2\phi_F + \frac{Q_B}{C_{ox}} \times \left\{ 1 - \left[ \left( 1 + \frac{2w_D}{\gamma_j} \right)^{1/3} - 1 \right] \left[ \frac{\gamma_j}{L} + \frac{2w_x \gamma_j}{WL} \right] + \frac{2w_x}{W} \right\}. \quad (1)$$

in which  $\phi_{ms}$  is the metallic semiconductor power coefficient difference.  $C_{ox} = \epsilon_{ox}/t_{ox}$  is the unit surface area oxidized film capacitance.  $\phi_F$  is the Fermi force of the substrate.  $Q_B = (4q\epsilon_s N_A \phi_F)^{1/2}$ .  $w_D$  is width of the depletion layer when the substrate offset voltage is zero,  $w_D = w_x$ . In equation (1),  $V_T$  is the function of the six variables:  $t_{ox}$ ,  $Q_{ss}$ ,  $N_A$ ,  $L$ ,  $W$ , and  $\gamma_j$ .

The average values of the six input variables and the root-mean-square difference are selected with reference to the actual situation. The rise and fall of the actual variables in the vicinity of their average values is normal distribution. Six groups of standard normal distribution random numbers are produced, then are converted into normal distribution of the variables. Substituted in (1)  $V_T$  is calculated. Each group in this task has 1000 random numbers. Recomputing 1000 times arrives at 1000  $V_T$ .

The sensitivity  $S$  of  $V_T$  is defined as<sup>3</sup>:

$$S = \left( \frac{\text{output distribution width when a single input variable changes X 95\%}}{\text{output distribution width when each input variable changes X 95\%}} \right)^2 \times 100\% \quad (2)$$

The numerator in equation (2) is the change of an input variable, when the other items are fixed in average values, the distribution width of  $V_T$  is broader. The denominator is the distribution width of output  $V_T$  when all the input variables change. The two xiangchu [4161 7110] represent the relative contribution of changes in the variable with regard to the  $V_T$  distribution. It is expressed in percentages.

By selecting different average values for  $L$  and recalculating equation (2) one can get the sensitivity  $S$  of  $V_T$  with regard to different variables as  $L$  changes.

### III. Conclusion and Analysis

The average values and standard deviation of the six input variables are taken in accordance with actual circumstances.  $t_{ox}(\text{\AA}): 500, 20$ ;  $N_A(10^{16}\text{cm}^{-3}): 6, 1$ ;  $Q_{ss}(10^{11}\text{cm}^{-3}): 2.5, 0.2$ ;  $\gamma_j(\mu\text{m}): 0.5, 0.03$ ;  $W(\mu\text{m}): 10, 0.3$ ;  $L(\mu\text{m}): 0.7-4, 0.15$ .

Table 1 is the sensitivity  $S$  of  $V_T$  to variables when  $L$  is different. As  $L$  changes, the sensitivity of the variables changed. Figure 1 is the curve drawn from the data of Table 1. The horizontal axis is  $L$  and the vertical axis is  $S$ . Each curve represents the  $S$  of  $V_T$  to that variable as  $L$  changes. The  $S$  of  $V_T$  to  $\gamma_j$  and  $W$  is nearly zero, and these two curves are not drawn in Figure 1.

Table 1. Sensitivity  $S(X100\%)$  of  $V_T$  to Variables When  $L$  Is Different

$L(\mu m)$	0.7	0.8	0.9	1.0	1.25	1.5	2.0	3.0	4.0
$S$									
$S(N_A)$	0.01	0.02	0.03	0.04	0.05	0.05	0.05	0.05	0.05
$S(t_{ox})$	0.10	0.19	0.27	0.33	0.42	0.46	0.49	0.52	0.53
$S(Q_{ss})$	0.13	0.22	0.31	0.36	0.43	0.44	0.44	0.44	0.44
$S(\gamma_f)$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$
$S(W)$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$	$\sim 0$
$S(L)$	0.76	0.57	0.39	0.27	0.11	0.05	0.01	$\sim 0$	$\sim 0$

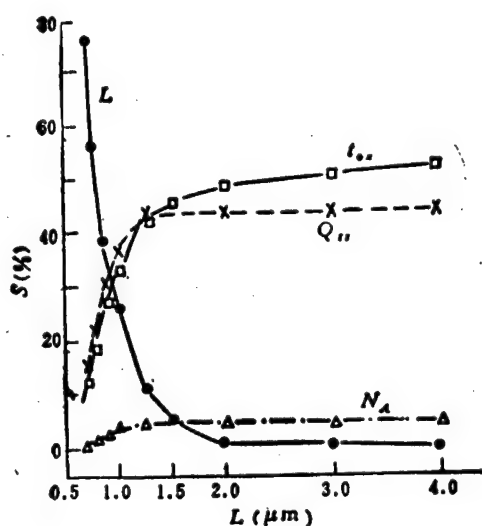


Figure 1. Sensitivity  $S$  of  $V_T$  to Variables With Changes in  $L$

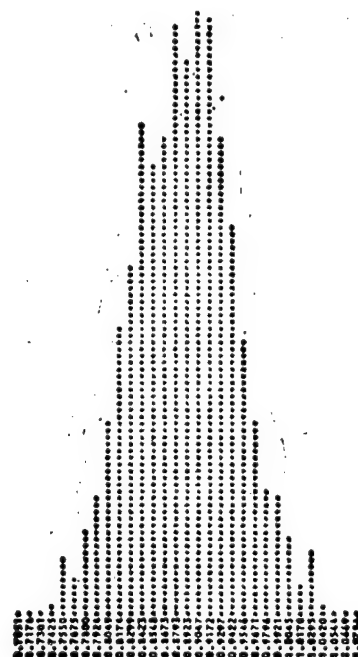


Figure 2.  $V_T$  Distribution

Figure 2 is a distribution chart of 1000  $V_T$ s when  $L = 1.25 \mu m$  and the six variables change simultaneously. In the figure,  $(V_T)_{min} = 0.7051 V$ ,  $(V_T)_{max} = 1.0794 V$ . The actual average value is  $0.8833 V$ . This figure shows that the  $V_T$  distribution is close to normal distribution. The standard deviation is calculated at  $0.0569 V$ .

The above results show:

- (1) The criterion equation for short channel effect is<sup>4</sup>:

$$L_{min} = 0.4[\gamma_f t_{ox}(W_s + W_d)^2]^{1/3}. \quad (3)$$

in which  $W_s$  and  $W_d$  are the potential width of the source and drain, respectively. Substituting the data used in this article we get  $L_{min} = 1.7 \mu m$ .

Due to the sensitivity of  $V_T$  to  $L$  [Table 1], at about  $L = 2.0 \mu m$ , the short channel effect begins to appear. This is close to the results of criterion equation (3).

(2) When  $L > 3 \mu m$ , the  $S$  value of  $V_T$  to  $L$  is close to zero. The value for  $t_{ox}$  and  $Q_{ss}$  is higher. After  $L$  drops to  $1.5 \mu m$ , the  $S$  value of  $V_T$  to  $t_{ox}$ ,  $Q_{ss}$  and  $N_A$  clearly declines, and  $L$ 's  $S$  value rises sharply. This shows that the short channel effect is reflected in the sensitivity  $S$ .

(3) The distribution of  $V_T$  is normal. Therefore, component simulation using the Monte Carlo method can predict the rate of finished components.

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PHYSICAL SCIENCES

CHARACTERISTICS OF BORON, ARSENIC DOUBLE IMPLANTATION IN SILICON STUDIED

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[Article by Ma Yi [7456 6146], Li Guohui [2621 0948 6540], and Zhang Tonghe [1728 6639 0735], Low-Energy Nuclear Physics Institute, Beijing Normal University, and Huang Chang [7806 2412], Li Shan Microelectronic Company: "Measurement of the Carrier Profile of Boron and Arsenic Double Implantation in Silicon and Its Simulation"; paper received on 8 February 1985]

[Text] English Abstract: The characteristics of boron and arsenic double implantation in silicon are studied and the interaction between these two elements are discussed. An exponential decreased electrical field is used to simulate the dip of base carrier profile near E-B junction and an effective diffusivity is used to simulate the effect of enhanced diffusion in the tail region. A computer program is made to calculate the carrier profile of boron and arsenic double implantation in silicon.

I. Introduction

With the development of LSI and VLSI, ion implantation technology has received serious attention more and more. People must understand the boron and arsenic implantation and the laws of carrier distribution after thermal annealing in bipolar components to provide information for circuit designers.

II. Experiments in Boron and Arsenic Double Implantation Carrier Density Distribution, Results and Analysis

A. Experimental Method

The experimental material was P<111>, a substrate of resistance 8-13 $\Omega$ ·cm grown 5-6  $\mu$ m thick and an n-type epitaxial layer of resistance 0.35-0.40 $\Omega$ ·cm. Boron and arsenic were the base area and the emitter dopant, respectively. To avoid a 7° sample angle at channel implantation time, after some of the sample was implanted with boron, when the arsenic was implanted, aluminum foil was used to shield a part. After the sample had been manufactured, the differential conductance method was used to measure the carrier concentration distribution. A DT-830 digital multimeter was used to measure the current, with a precision of (reading + three times the floating point number)  $\times 1.0$

percent, a voltage was measured with a DME-1400, with a precision of 0.04 percent  $\times$  the reading + 0.02 percent  $\times$  the measuring range, the measuring range was 200 mV, a TP-77 tuopianyí [2900 0252 0308] was used to measure the  $\text{SiO}_2$  film thickness, with a precision of  $\pm 20 \text{ \AA}$ , and digital processing was carried out by a computer.

## B. Experimental Results and Analysis

### 1. Comparison of Boron Single Implantation and Boron and Arsenic Double Implantation

In Figure 1 one can see that the base region carrier concentration dips in the vicinity of the E-B junction which can be accepted as the result of internally constructed electrical field action. In the high temperature thermal annealing process, after the implantation ions have been activated, the donor ions carry positive charge, and because the mass of the ions is many times greater than the carrier, the carrier always diffuses faster than the ions. However, due to the demands of local electricity neutrality, the existence of the ions also suppresses the diffusion of the carrier, and this creates an internally constructed electrical field. This electrical field accelerates the diffusion of the donor into the silicon and suppresses the diffusion of the acceptor, because after the acceptor is ionized, it carries a negative charge. In Figure 2, the peak position distance of the E-B junction is farther and the dip is not severe since the boron implantation energy is high.

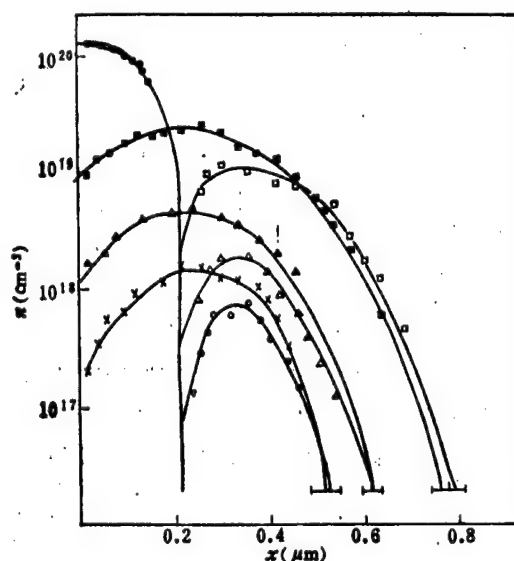


Figure 1. Comparison of Carrier Concentration Distribution of Boron Single Implantation and Boron-Arsenic Double Implantation  
 Boron single implantation 70keV, 1000°C, 30' annealing,  
 ■  $1 \times 10^{15}/\text{cm}^2$ , ▲  $2 \times 10^{14}/\text{cm}^2$ , ×  $6 \times 10^{13}/\text{cm}^2$ ,  
 Arsenic implantation 80keV,  $2 \times 10^{15}/\text{cm}^2$ ,  
 Boron double implantation □  $1 \times 10^{15}/\text{cm}^2$ , Δ  $2 \times 10^{14}/\text{cm}^2$ , ○  $6 \times 10^{13}/\text{cm}^2$



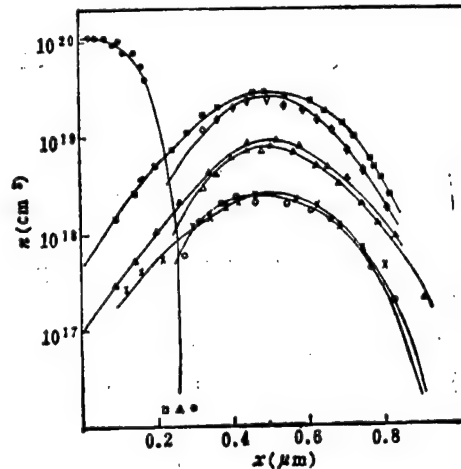


Figure 2. Influence of Different Implantation Dosages of Boron  
 Boron single implantation, 160keV, 950°C, 30' annealing,  
 ■  $1 \times 10^{15}/\text{cm}^2$ , ▲  $2 \times 10^{14}/\text{cm}^2$ , x  $6 \times 10^{13}/\text{cm}^2$ ,  
 Dual implantation: ● Arsenic implantation 80keV,  $2 \times 10^{15}/\text{cm}^2$ ,  
 Boron: □  $1 \times 10^{15}/\text{cm}^2$ , △  $2 \times 10^{14}/\text{cm}^2$ , o  $6 \times 10^{13}/\text{cm}^2$

## 2. Influence of Different Boron Implantation Dosages

In Figure 2 we can also discover that as the boron implantation dosage increases, the entire distribution of the base region translates upwards, and at the same time since the donor and acceptor compensation increases making the emitter region concentration dip, and the E-B junction become shallower.

## 3. Influence of Different Implantation Sequences

In Figure 3 we can see that the differences between the two 950°C+1000°C annealings and the one 1000°C annealing are not great. The two curves basically overlap, but there is a broader base region than the single 950°C annealing. For the sample in which the As was implanted first and the B implanted afterwards, since there was 30' annealing at 1000°C after the As was implanted, the E-B junction is already rather deep, and more of the boron is located below the emitter region, and added to the fact that the annealing temperature is also low, it leads to a rather thin base region.

## 4. Influence of Double Implantation on B-C Junction Depth

Figure 4 is an angle lap stain microscopic photograph enlarged 800 times, and one can see that the double implanted region is level with the bottom of the boron single implantation region boundary. It can be seen that under the technological conditions demanded by components in general, the influence of implantation of the B-C junction can be overlooked.

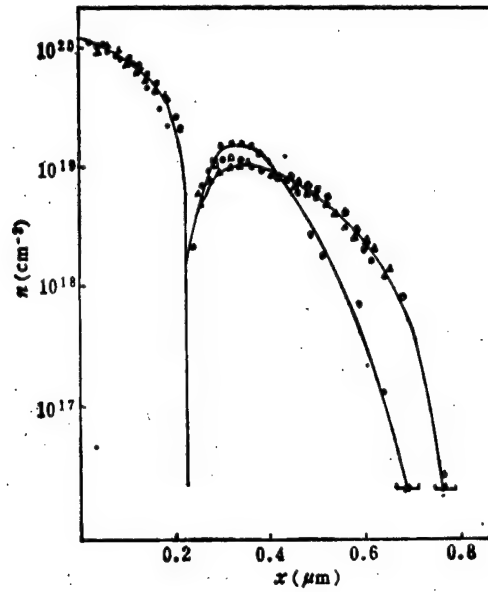


Figure 3. Comparison of Different Implantation Sequences

- ▲ B<sup>+</sup>950°C, 30' + As<sup>+</sup>1000°C, 30'
  - B<sup>+</sup> + As<sup>+</sup>1000°C, 30'
  - ⊙ As<sup>+</sup>1000°C, 30' + B<sup>+</sup>950°C, 30'
- B<sup>+</sup> implantation 70 keV, 1x10<sup>15</sup>/cm<sup>2</sup>  
 As<sup>+</sup> implantation 80 keV, 2x10<sup>15</sup>/cm<sup>2</sup>



Figure 4. Influence of Double Implantation on B-C Junction  
 Boron 70 keV, 2x10<sup>14</sup>/cm<sup>2</sup> + As<sup>+</sup>80 keV, 5x10<sup>15</sup>/cm<sup>2</sup>, 1000°C, 30'

### III. Computer Simulation

#### A. Simulation of Emitter Region Carrier Distribution

We used Fair's<sup>1</sup> method. The impurity concentration after arsenic implantation could be expressed using Chebyshev's equation:

$$N/N_0 = 1.00 - 0.87Y - 0.45Y^2. \quad (1)$$

For ion implantation samples, conditions of implantation dosages below  $5 \times 10^{15}/\text{cm}^2$  require only  $1000^\circ\text{C}$ , 20' annealing to achieve a 100 percent activation rate<sup>2,3</sup>, therefore equation (1) can be viewed as an approximate emitter region carrier concentration distribution.

#### B. Simulation of Base Region Carrier Distribution

An exponential decay field can be used to simulate the internally constructed electrical field of the E-B junction. The ion flow when there is an external force field is:

$$J = -D \frac{\partial N}{\partial x} - e \mu N E_x. \quad (2)$$

We suppose

$$E_x = E_{\max} e^{-\left(\frac{x-x_0}{\lambda}\right)}. \quad (3)$$

On the basis of the relationship between the experimental curve simulated  $E_{\max, \lambda}$  and the technological conditions, we can extend it to a broader range.

### IV. Circuit Applications

1. High speed ECL circuits (created in cooperation with the Computer Institute of the Chinese Academy of Sciences)

B<sup>+</sup> implantation 10keV,  $2 \times 10^{12}/\text{cm}^2$ , 20keV,  $6 \times 10^{12}/\text{cm}^2$ , 40keV,  $1 \times 10^{13}/\text{cm}^2$ , 60keV,  $6 \times 10^{13}/\text{cm}^2$ ,  $850^\circ\text{C}$ , 30' annealing, As<sup>+</sup> implantation 80keV,  $5 \times 10^{15}/\text{cm}^2$ ,  $1000^\circ\text{C}$ , 25',  $\beta = 20-40$ ,  $V_{CE} = 14\text{V}$ ,  $V_{EB} = 4-6\text{V}$ .

2. TTL circuits (created in cooperation with the Li Shan Microelectronics Company)

B<sup>+</sup> implantation 60keV,  $6 \times 10^{13}/\text{cm}^2$ ,  $960^\circ\text{C}$ , 30', As<sup>+</sup> implantation, 80keV,  $5 \times 10^{15}/\text{cm}^2$ ,  $1000^\circ\text{C}$  20',  $\beta = 100$ ,  $V_{CE} = 10\text{V}$ .

3. LS-TTL circuits and L-TTL circuits (created in cooperation with the 109 Plant of the Chinese Academy of Sciences)

B<sup>+</sup> 60keV,  $8 \times 10^{14}/\text{cm}^2$ ,  $950^\circ\text{C}$ , 30', As<sup>+</sup> 80 keV,  $5 \times 10^{15}/\text{cm}^2$ ,  $1050^\circ\text{C}$ , 30',  $\beta = 10$ ,  $V_{CE} = 25\text{V}$ ,  $V_{BC} = 35\text{V}$ ,  $V_{EB} = 6\text{V}$ .

The authors express their heartfelt thanks to our teacher Han Shuyun [3944 3219 5366], the Li Shan Microelectronics Company, Academy of Sciences 109 Plant, the Academy of Sciences' Computer Institute, this institute's Accelerator Laboratory, Computer Room, and Comrades Lu Xianshu [0712 6343 3219], Wang Qi [3769 3823], and Li Xiaoming [2621 2556 2494] for their great help.

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PHYSICAL SCIENCES

INTERFACE REACTIONS, VACUUM ANNEALING EFFECTS OF MBE Al/GAAS

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese  
Vol 7, No 2, Mar 86 pp 198-201

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Xing Yirong [6717 4135 2837], Sun Dianzhao [1327 3013 3564], and Shen  
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[Text] I. Introduction

The formation of Schottky junction by Al-GaAs (100) contact plays an important role in such devices as microwave frequency mixers, field effect tubes, CCD's and in large scale GaAs integrated circuits. In the manufacturing of Schottky junctions, the semi-conductor is generally contaminated due to exposure to the atmosphere. We use the technique of molecular beam epitaxy (MBE) to grow GaAs epitaxy under ultra-high vacuum conditions, and achieved ideal Schottky contact at the epitaxial Al monocrystal layers, thus removing oxygen and other impurities.

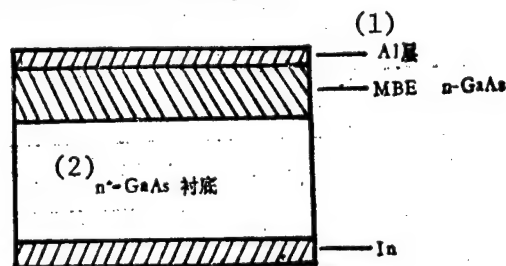
In addition to using electrical technique to measure the properties of Al/GaAs(100) Schottky junction, we also apply surface analysis (AES and XPS) and Raman spectral techniques to study the interface structure. This technique provides a better understanding of the electrical properties of the equipment as well as the relationship between interface reaction and its structure; for this reason, it is a useful tool for designing and manufacturing semi-conductor components. Interface reaction has always been a topic of considerable interest; it has been observed that AlAs layer is formed at the interface by depositing Al on the GaAs(110) surface. [1,2,3] We have also observed AlAs compound at the interface of As-rich GaAs(100, and discovered the formation of solid solution  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  as a result of the exchange of Al and Ga atoms in the GaAs epitaxy. In addition, the heat treatment process will affect the electrical properties of the Schottky junction, and promote the interdiffusion of interface elements and the interface reaction; consequently, the Schottky barrier height will increase with increasing annealing temperature.

II. Experiment

A molecular beam epitaxy device, developed jointly by this laboratory and the Shenyang Scientific Instrument Factory, is used to grow Al/GaAs(100)

test samples, whose structure is shown in Figure 1. It has a substrate made of  $n^+$ -GaAs(100) mixed with Te, and uses pure As(6N), pure Ga(6N), and pure Al(6N) as substances for the molecular beam. Prior to epitaxial growth, the substrate is first polished using a chemical-mechanical process and flushed with organic solution and de-ionized water; then it is subject to chemical corrosion using a solution of  $H_2SO_4 : H_2O_2 : H_2O = 7:1:1$ . After being flushed with de-ionized water and blow-dried, the substrate is immediately bonded to a Mo block with In, and placed in an ultra-high vacuum growth chamber. When heated to a temperature of  $580^\circ C$  under a specified As steam pressure, a clean growth surface is obtained by removing the oxidized layer and other impurities attached to the surface; at the same time, In and the  $n^+$ -GaAs substrate combine to form a good Ohm junction. In order to obtain an ideal Al-GaAs structure, we first produce a Si-mixed,  $n$  type GaAs layer approximately 1 micron thick; the growth conditions are as follows: the substrate temperature is  $580^\circ C - 680^\circ C$ ; the ratio of As/Ga flow rates is 5-10; and the growth rate is 1 micron/hour. The RHEED observation of the epitaxial surface shows that it has an As-rich, GaAs(100)-C(2x8) structure. The carrier concentration of the MBE using the Hall effect technique is  $5 \times 10^{15} \text{ cm}^{-3}$ . One hour after GaAs epitaxy is completed, the substrate is cooled to  $\sim 50^\circ C$ ; and with the As steam pressure reduced to less than  $1 \times 10^{-8}$  torr, a MBE Al film is formed on the GaAs(100) surface. Its growth rate is 40 Å/min, and the thickness of the Al film is 1200 Å; the RHEED observation of the Al film shows that it has a single crystal structure. The annealing process of the test sample is carried out in a vacuum chamber at temperatures of  $350^\circ C$  and  $450^\circ C$  for a period of 30 minutes.

Figure 1. Structure of an Al/GaAs Sample



Key: 1. Al layer                      2.  $n^+$ -GaAs substrate

After being removed from the MBE growth chamber, the Al/GaAs slice is divided into two halves. One half of the slice is placed in a PHI-550 electronic spectrometer vacuum chamber, the other half is subject to a photoetching process to produce two circular Al-film Schottky diodes with diameters of 500  $\mu m$  and 700  $\mu m$  respectively.

A systematic study of the electrical properties of Schottky junctions has been carried out using I-V and C-V measurement systems. The electric current of I-V is measured by a M194-  $\mu A$  ammeter and a TR-B4M oscillatory electrometer, whose measurement accuracy is  $\pm 1$  percent. In C-V measurements, a Boonton 76A capacity meter is used to measure the junction capacitance;

its measurement accuracy is better than  $10^{-5}$  pF. The optical measurement of the test sample is made using a T800 laser Raman Spectrometer. It uses a near- $180^\circ$  back-scattering arrangement, and the light source is a 4880 Å Ar-ion laser. AES and XPS measurements are carried out using a PHI-550 electronic spectrometer under  $2 \times 10^{-9}$ -torr high-vacuum conditions. In making AES measurements, the energy level of the incident electron beam is 5 keV, and the beam current is 3  $\mu$ A. The sputtering voltage of the  $\text{Ar}^+$  ions is 2 kV, and the beam current is 1.35  $\mu$ A.  $\text{MgK}\alpha$  X-ray is used as the excitation light source for XPS; the passing energy level is 50 eV, and the number of integrated signals is 30-50. Pure gold samples are also tested using the  $4f_{7/2}$  peak as the standard peak.

### III. Results and Discussion

#### 1. Variation of the Electrical Properties of Schottky Junction With Annealing Temperature

Electrical measurements have been taken on both the unannealed MBE Schottky junctions and junctions which are annealed in vacuum under  $350^\circ\text{C}$  and  $450^\circ\text{C}$ . In C-V measurements, the Schottky barrier height is determined through the differential capacitance in the depletion layer as a function of the externally applied inverse voltage; in I-V measurements, the barrier height is determined using theoretical formulas for thermal electron emissions; the results are presented in Table 1. Both measurement techniques show that the interface Schottky barrier increases after heat treatment. These results are in agreement with the results of Johnson et al.<sup>[4]</sup> and those of Thorwald et al.<sup>[5]</sup> For unannealed Schottky junctions and junctions annealed at  $350^\circ\text{C}$ , the  $C^{-2}$  varies linearly with V, with an ideal factor of 1.05. When the annealing temperature reaches or exceeds  $450^\circ\text{C}$ , the C-V and I-V characteristics begin to deteriorate, and both the inverse leakage current and the ideal factor increases.

Table 1

(1) 热处理温度		(2) 室温	$350^\circ\text{C}$	$450^\circ\text{C}$
(3) 势垒高度(eV)	C-V	0.78	0.90	1.1
	I-V	0.62	0.68	0.73

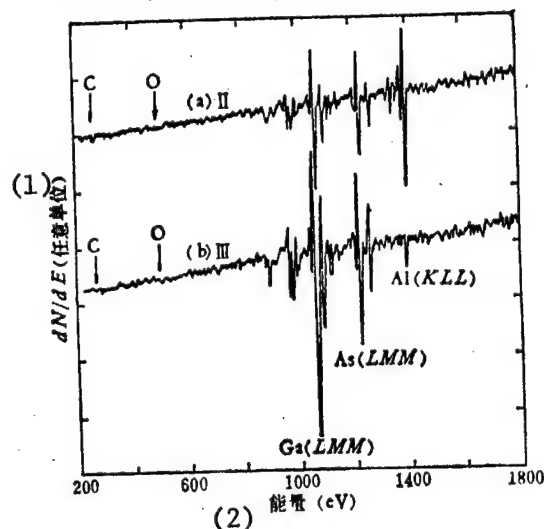
Key: 1. Annealing temperature  
2. Room temperature  
3. Barrier height (eV)

#### 2. Distribution of Interface Constituents and the Interdiffusion Caused by Heat Treatment

The constituents of the MBE Al/GaAs structure under different heat treatment conditions are measured using an Auger electronic spectrometer. Figure 2 shows the AES at the interface. The arrows in the figure point

out the absence of O and C peaks, i.e., the absence of O and C elements. This illustrates that the Schottky junction produced by MBE technique is an ideal junction which contains no impurities. On the other hand, the Schottky junction produced by conventional techniques contains oxygen and other impurities because the semiconductor surface is exposed to air and therefore subject to oxidization and contamination.

Figure 2. AES at the Interface of MBE Al/GaAs(100). The spectra (a) and (b) are measured near the interfaces of the Al film (II) and the GaAs epitaxial layer (III) respectively.

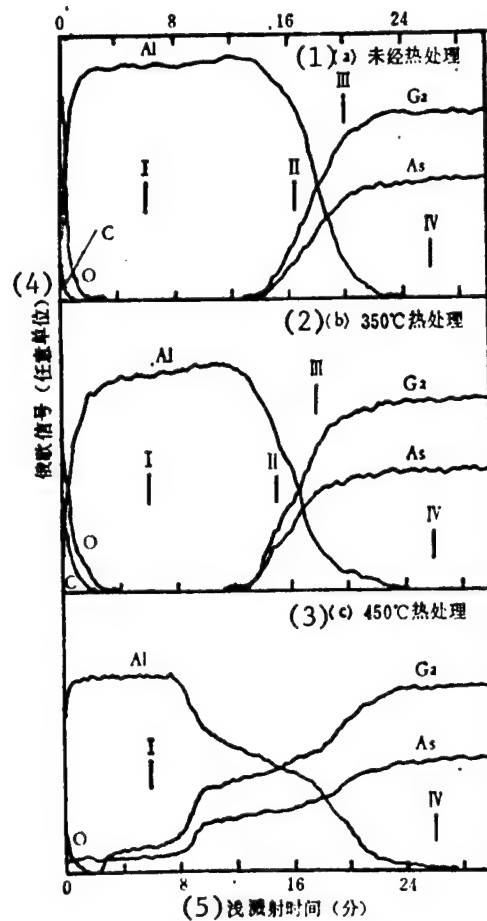


Key: 1. Arbitrary unit  
2. Energy level

Figure 3 shows the depth distributions of the sample constituents under different annealing temperatures. By using an  $\alpha$  step tracing instrument, the sputtering rates of the  $\text{Ar}^+$  ions are determined to be  $\sim 60 \text{ \AA/min}$  relative to the Al film and  $\sim 30 \text{ \AA/min}$  relative to the GaAs epitaxy. We can see from Figure 3 that the interface element distributions for unannealed samples are very steep (Figure 3(a)). Samples which are annealed at  $350^\circ\text{C}$  show no apparent element interdiffusion effect; the element distribution at the interface is still very steep, but the transition region at the interface extends  $30\text{--}60 \text{ \AA}$  in the direction of the Al layer (Figure 3(b)). The I-V characteristics of the Schottky diodes made from the same slice are still very good. However, for samples which are annealed at  $450^\circ\text{C}$ , the Ga and As elements almost diffuse through the entire Al layer, and the Al element diffuses into the surface layer of the epitaxial GaAs (Figure 3(c)). The apparent interdiffusion of Al and GaAs destroys the ideal step junction, thus causing deterioration of the electrical properties of the Schottky junction. Therefore, in the manufacturing process of Al/GaAs(100) Schottky junction using molecular beam epitaxy technique, we must ensure that the slices are not subject to temperature higher than  $450^\circ\text{C}$ .



Figure 3. Depth Distribution of the Constituents of Al/GaAs Structure Under Different Annealing Temperatures



Key: 1. (a) Unannealed  
 2. (b) Annealed at 350°C  
 3. (c) Annealed at 450°C  
 4. Auger signal (arbitrary unit)  
 5. Sputtering time (minutes)

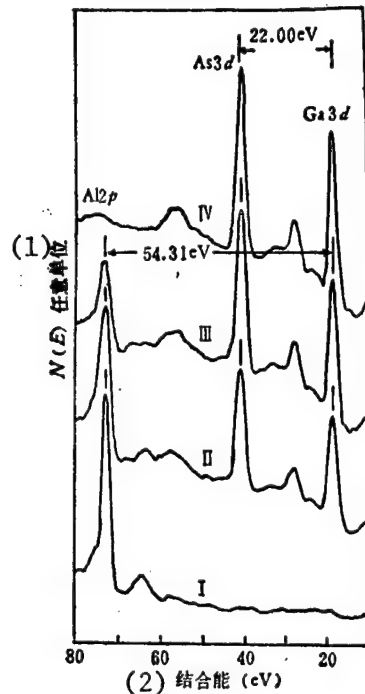
### 3. Interface Reaction

The interface chemical reaction of metal GaAs is important for the stability and reliability of its Schottky junction. Metals such as Al, Au and Cr can also react chemically with the semiconductor GaAs, and cause it to have the tendency to decompose.<sup>[1]</sup> The XPS used in chemical analysis can provide useful information on the chemical bond. For this reason, we perform XPS measurements of the I-IV cross-sections of test samples annealed at different temperatures; for example, the test results of samples annealed at 350°C are shown in Figure 4. The difference in binding energies between the As3d and Ga3d peaks in the interface region (II and III in Figure 4) is measured to be 22.00 eV, which is the same as that in the GaAs epitaxial layer (IV); this illustrates that there is

no chemical displacement in the As3d and Ga3d core energy levels. Also, the difference in binding energies  $\Delta E_b$  between the Al2p and Ga3d core energy levels is measured to be 54.31 eV. This result is in close agreement with the result of Waldrop et al.<sup>[6]</sup> where  $\Delta E_b$  is measured to 54.25 eV from XPS spectra in the study of MBE AlAs-GaAs heterojunctions.

Figure 4. Core Energy Spectra of MBE Al/GaAs(100) Structure.

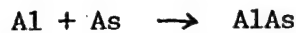
The cross-section locations of spectrum I through spectrum IV are shown in Figure 3. Spectrum I is measured within the Al film; spectrum II and spectrum III correspond to the interface regions near the Al film and the GaAs respectively; spectrum IV is within the GaAs layer.



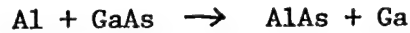
Key: 1. Arbitrary unit

2. Binding energy

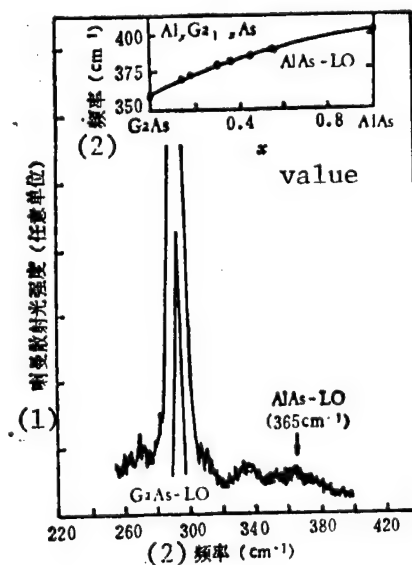
This illustrates that AlAs compounds are present at the MBE Al/GaAs(100) interface. The formation of AlAs and the displacement of the Al2p peak due to interface chemical reaction are also confirmed. In the core energy spectra containing both Al2p peaks and standard Au4f<sub>7/2</sub> peaks (scan range is 65-85 eV), we have measured a 0.6 eV displacement of the Al2p peak toward higher binding energy level. The movement of the Al2p peaks can also be seen from Figure 4; it is in agreement with the results reported by Kahn et al.<sup>[3]</sup> in a study of the Al and GaAs(110) interface. Because As has a higher negative charge (2.0) than Al(1.5), during the chemical reaction in which formation of Al-As bond takes place, the Al atoms will undergo charge transfer, resulting in increased binding energy at the core energy level. There are two types of chemical reactions which form AlAs compounds at the Al-GaAs(100) interface: one is the direct combination of Al atoms with the rich As atoms on the MBE GaAs(100)-C(2/8) surface:



the other is the displacement reaction between Al and GaAs:



It is generally believed that in the GaAs layer, Ga is displaced by Al to form AlAs<sub>24</sub>; however, this can occur only if the Al atoms displace all 4 Ga atoms surrounding As, just like the displacement reaction in the interface region. In fact, the Al atoms which enter the GaAs layer only partially replace Ga to form the solid solution AlGa<sub>1-x</sub>As. To confirm this point, measurements are performed using Raman scattering spectral techniques. The measured results have demonstrated that the optical technique is an effective way to identify the type of Al-Ga displacement reaction which would be difficult to identify by XPS measurements. The MBE Al/GaAs slice is treated with a chemical corrosion process to remove the top layer of Al film; what remains after Al removal is used as the sample for optical measurement. The Raman spectrum obtained by shooting a laser beam into the test sample is shown in Figure 5. The 292 cm<sup>-1</sup> main peak of the spectrum corresponds to the generic GaAs-LO mode, and the 365 cm<sup>-1</sup> weak peak corresponds to the generic AlAs-LO mode. But the nature of the small peak in the vicinity of the main peak (at a frequency of approximately 330 cm<sup>-1</sup>) is still not clear. In a study of the modal frequency of the long-wave-length optical phonon of the solid solution AlGa<sub>1-x</sub>As, Kim et al.<sup>77</sup> discovered that the modal frequency increases with the value of x. For example, when x increases to 1 (i.e., AlAs compound), the modal frequency of the generic AlAs-LO is approximately 400 cm<sup>-1</sup>, as shown in the top insert of Figure 5 (the solid curve and the circles are respectively the theoretical curve and the experimental points given by Kim et al). It can be seen from Figure 5 that the generic AlAs-LO peak is located at the frequency 365 cm<sup>-1</sup>, and no peak exists at the frequency 400 cm<sup>-1</sup>. This illustrates that the Al-Ga displacement reaction only forms the solid solution AlGa<sub>1-x</sub>As (x < 1); it does not produce any AlAs compound (x=1). The diffusion coefficient of Al in GaAs is very small; even at a high annealing temperature of 450°C, only a small amount of Al atoms would enter into the GaAs surface layer. From the depth distribution of sample constituents indicated in Figure 3(c), one can roughly estimate the GaAs surface layer to be approximately 200 Å in thickness.



- Key: 1. Raman scattered light intensity  
2. Frequency

#### IV. Conclusion

From the results of electrical and optical measurements and from surface analysis, the following conclusions can be drawn:

1. An ideal Schottky junction with no oxides or other impurities can be obtained using molecular beam epitaxy techniques.
2. When the annealing temperature exceeds 450°C, element interdiffusion occurs at the interface between the metal and the semiconductor; Ga and As almost diffuse into the entire Al layer, thereby causing deterioration of the electrical properties of the Schottky junction. Therefore, elevated temperature should be avoided in manufacturing Schottky diodes.
3. By depositing Al on the MBE As-rich GaAs(100)-C(2x8) surface, interface reaction will take place and AlAs compounds will form in the interface region. Heat treatment will promote interface reaction and increase the Schottky barrier height.
4. The Al atoms which diffuse into GaAs will partially displace Ga to form  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  solid solution.

Thanks are due to Comrade Wang Zhaoping and Comrade Han Hexiang for their assistance in making Raman spectral measurements during this experiment.

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PHYSICAL SCIENCES

TWO-DIMENSIONAL ELECTRON GAS IN MBE GROWN SELECTIVELY DOPED GaAs/N-AlGaAs  
HETEROSTRUCTURES

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7  
No 2, Mar 86 pp 216-218

[Article by Jiang Pihuan [3068 0012 2719], Li Yuexia [2621 2588 7209], Yang Fuhua [2799 1381 5478], and Wang Xinghua [3769 2622 5478], Institute of Semiconductors, Chinese Academy of Sciences: "Two-Dimensional Electron Gas in MBE Grown Selectively Doped GaAs/N-AlGaAs Heterostructures," received 20 March 1985]

[Text] English Abstract: Transport properties of two-dimensional electron gas in MBE grown selectively doped GaAs/N-AlGaAs heterostructures have been measured in strong magnetic field at low temperature. SdH oscillation and quantized Hall effect have been observed.

Our institute's MBE group manufactured a selectively doped GaAs/N-AlGaAs heterostructure whose structure is as follows: First we grew epitaxially a 1  $\mu\text{m}$  thick non-doped GaAs layer on a Cr semi-insulated (100) GaAs substrate, then an isolation layer of non-doped  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  about 60  $\text{\AA}$  thick was grown, on top of which was an Si mixed N- $\text{Al}_x\text{Ga}_{1-x}\text{As}$  layer 1000  $\text{\AA}$  thick with a dopant concentration of approximately  $1.0 \times 10^{18} \text{ cm}^{-3}$ , and finally on the surface was built a 200  $\text{\AA}$  non-doped GaAs layer. The AlAs gram molecular number  $x$  was about 0.3. The electrons produced by the donor impurity Si in the  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  transferred to the GaAs side of the boundary surface, and formed two-dimension electron gas in the vicinity of the boundary.

For measuring, we used the alloy method to manufacture an indium electrode, with the electrode distribution being Van der Pauw's equation. We made the boundary surface of the heterostructure perpendicular to the magnetic field and at low temperature measured the relationship of the specific resistance tensors  $\rho_{xx}$  and  $\rho_{xy}$  with changes in the magnetic field intensity  $B$ . See Figure 1 for typical results.

In a weak magnetic field,  $\rho_{xy}$  and  $B$  are in direct proportion, their ratio being Hall's coefficient  $R$ , and using the classical equation

$$R = \frac{1}{Nec} \quad (1)$$

we can compute the electron concentration.

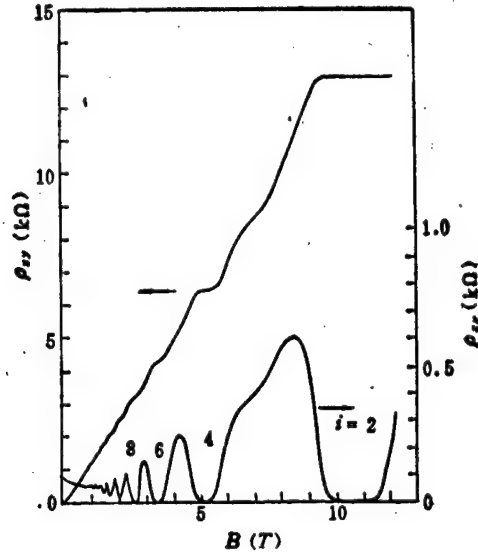


Figure 1. Relationship of  $\rho_{xx}$  and  $\rho_{xy}$  with changes in the magnetic field intensity  $B$ . No 84147,  $T = 2.5K$ ,  $\rho_{xx}$ :  $I = 50 \mu A$ ,  $\rho_{xy}$ :  $I = 10 \mu A$

In a stronger magnetic field, we observed that the extremely small values of the quantized Hall effect ( $\rho_{xy}$ ),  $\rho_{xx}$  and the SdH oscillation ( $\rho_{xx}$ ) was in platform correspondence with  $\rho_{xy}$ . In the  $n = 1$  Landau energy level we observed spin-spin splitting. When the electrons have just filled the Landau energy level of quantum number  $n$ , the concentration is

$$N = 2(n + 1) \frac{eB}{hc} - i \frac{eB}{hc}, \quad (2)$$

in which  $eB/hc$  is the degeneracy of the Landau energy level, the integer  $i = 2(n+1)$  expresses the Landau energy level filled with electrons. From equation (2) we can tell that the following equation is suitable for making  $\rho_{xx}$  appear the extremely small magnetic field intensity  $B_{min}$

$$(B_{min})^{-1} = \frac{i}{N} \frac{e}{hc}. \quad (3)$$

The relationship of the integer and the  $(B_{min})^{-1}$  obtained from experiments was drawn as a curve (Figure 2) in which the dots form a straight line. From this we can tell that they conform to equations (2) and (3), and we can identify the corresponding  $i$  value of the smallest value of  $\rho_{xx}$ . From the slope of the straight line we can find the electron concentration  $N$ .

Table 1 gives the relevant data of the two samples:  $\mu$  is the electron mobility,  $N_R$  is the electron concentration calculated from the Hall coefficient in a low magnetic field,  $N_{SdH}$  is the electron concentration calculated from the SdH oscillation. The electron concentrations obtained using the two methods are close, which indicates that conductance is produced from two-dimensional electron gas, and that the allied conductance can be ignored.

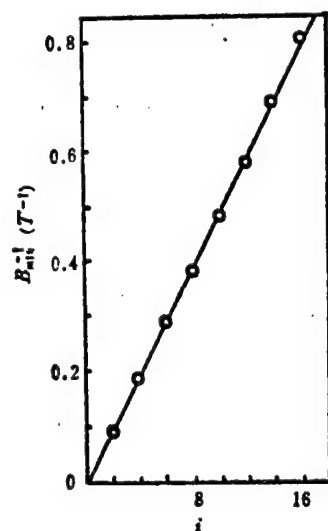


Figure 2. Relationship of  $B_{min}^1$  and the integer. No 84147

Table 1

Sample	Temperature	$\mu$ ( $m^2/V \cdot s$ )	$N_R$ ( $cm^{-2}$ )	$N_{SdH}$ ( $cm^{-2}$ )
84012	4.2	19	$3.7 \times 10^{11}$	$4.0 \times 10^{11}$
84147	2.5	14	$5.0 \times 10^{11}$	$5.0 \times 10^{11}$

When the relationship of  $\rho_{xy}$  with changes in  $B$  becomes a platform, the error of its deflection of the quantum Hall resistance theoretical value  $h/e^2$  is of a magnitude of  $10^{-3}$ . Figure 3 is the curve of the  $\rho_{xy}$  of samples of two different electron concentrations. From the figure it can be seen that the difference in electron concentration only changes numerical value of the magnetic field intensity  $B$  when the platform appears.

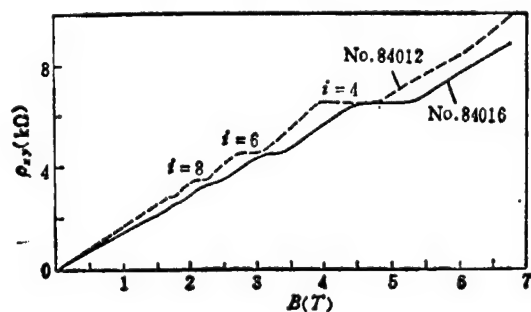


Figure 3. Relationship of  $\rho_{xy}$  of two samples of different electron concentrations with changes in  $B$ .

Sample No 84012  $N = 3.7 \times 10^{11} \text{ cm}^{-2}$

Sample No 84016  $N = 4.1 \times 10^{11} \text{ cm}^{-2}$

$T = 4.2K$ ,  $I = 50 \mu A$

The authors thank Cai Hong [5591 3126] and Dong Mouqun [5516 6180 5028] for their help in the experiments.

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PHYSICAL SCIENCES

EFFECT OF WATER COMPRESSIBILITY ON OCEANIC INTERNAL WAVE STUDIED

Qingdao SHANDONG HAIYANG XUEYUAN XUEBAO [JOURNAL OF SHANDONG COLLEGE OF OCEANOLOGY] in Chinese Vol 14 No 3, 15 Sep 84 pp 13-18

[Article by Fang Xinhua [2455 2946 5478] and Wang Jingming [3760 2529 2404], Department of Physical Oceanography and Marine Meteorology, Shandong College of Oceanography; paper received 31 August 1983]

[Text] 1. Description of the Problem

To calculate the Brunt-Vaisala frequency  $N$ , the following equation should be used when compressibility is taken into account:

$$N^2 = - \left( \frac{g}{\bar{\rho}} \frac{d\bar{\rho}}{dz} + \frac{g^2}{c_s^2} \right) \quad (1)$$

where  $\bar{\rho} = \bar{\rho}(z)$  is the density distribution at resting state,  
 $c_s$  is sound velocity in sea water, about 1500 m/sec,  
 $g$  is the acceleration due to gravity,  
 $z$  axis is vertical and pointing upward.

The term  $g^2/c_s^2$  in equation (1) represents the effect of compressibility on density and its magnitude is  $10^{-4} \text{ sec}^{-2}$ . From a sharp thermocline to deep down under the ocean,  $O(N^2)$  should be between  $10^{-4}$  and  $10^{-8} \text{ sec}^{-2}$ . It is obvious that even at a thermocline, the second term cannot be overlooked. Table 1 is from Knauss (1978) and the following relationship exists between stability  $E$  and the Brunt-Vaisala frequency  $N$ :

$$N^2 = E g$$

From the table, it can be seen that when the depth reaches 200 meters,  $O(N^2) = O(g^2/c_s^2)$ . Therefore, the density change due to compressibility cannot be ignored.

Many prominent investigators of internal wave use the incompressible model in their discussions of internal wave theory, that is the condition of incompressibility ( $\nabla \cdot \mathbf{V} = 0$ ) is present in their complete sets of fluid dynamic equations. Furthermore, a majority of them, e.g., Garrett and Munk (1972,

1975), Desaubies (1973), LeBlond and Mysak (1978), Turner (1979), and Phillips (1977), overlooked the north component of earth's rotation (i.e., the "classical approximation" was used). In dealing with internal wave problems, equation (1), which is a differential equation of internal wave derived under the assumption of incompressibility, is often used to address the effect of compressibility on N. So there lies a logical lapse. Some efforts of the authors to solve this problem is presented in this article. Attempts were made to examine the effect of compressibility through order of magnitude comparison, using the constant entropy assumption and the equations for vortexing, compressible fluid. Also the deep sea internal wave equations, applicable where N is small, were derived.

Table 1. The Distribution of Temperature, Salinity, and Stability With Depth (d, S, T, and E denote depth, salinity, temperature, and stability, respectively)

d(m)	S(‰)	T(°C)	E(10 <sup>-3</sup> m <sup>-1</sup> )	d(m)	S(‰)	T(°C)	E(10 <sup>-3</sup> m <sup>-1</sup> )
50	34.992	27.06	2500	1000	34.524	4.14	63
100	35.079	23.83	1800	1500	34.592	2.76	35
150	35.071	21.14	1400	2000	34.638	2.07	20
200	34.836	18.10	1200	3000	34.674	1.61	8
300	34.186	10.81	730	4000	34.688	1.48	3
500	34.271	6.54	230	5000	37.700	1.45	2
700	34.454	5.47	110				

## 2. Analysis of the Equations

Following the conventional coordinates system,  $x_1$ ,  $x_2$ , and  $z$  point east, north and up, respectively, and the origin is at the sea surface in equilibrium. There exist the vertical component  $f_1$  and north component  $f_2$  of earth's rotation:

$$f_1 = 2\Omega \sin\varphi,$$

$$f_2 = 2\Omega \cos\varphi,$$

where  $\Omega$  is the angular velocity of earth's rotation and  $\varphi$  is the latitude. Let's assume that

$$O(f_1) = O(f_2) = O(2\Omega),$$

i.e. exclude the equator and polar regions. Also assume that sea water is an ideal, compressible fluid and its motion is entropy-conserved, then the linear equations of motion for pulse momentum are:

$$\begin{cases}
\frac{\partial u_1}{\partial t} - f_1 u_2 + f_2 u_3 + \frac{1}{\rho} \frac{\partial p}{\partial x_1} = 0 \\
\frac{\partial u_2}{\partial t} + f_1 u_1 + \frac{1}{\rho} \frac{\partial p}{\partial x_2} = 0 \\
\frac{\partial u_3}{\partial t} - f_2 u_1 + \frac{\rho}{\rho} g + \frac{1}{\rho} \frac{\partial p}{\partial z} = 0 \\
\frac{\partial \rho}{\partial t} + u_3 \frac{\partial \rho}{\partial z} + \bar{\rho} \left( \frac{\partial u_1}{\partial x_1} + \frac{\partial u_2}{\partial x_2} + \frac{\partial u_3}{\partial z} \right) = 0 \\
\frac{\partial \rho}{\partial t} = \frac{1}{c_s^2} \frac{\partial p}{\partial t}
\end{cases} \quad (2)$$

The physical meanings of all notations used in the equations are the same as the conventional usages in the majority of internal wave literature and no further explanation is necessary.

Let each pulse momentum have a solution in the following form:

$$\begin{aligned}
\{u_1, u_2, u_3, p, \rho\} = \\
= \{U_1(z), U_2(z), U_3(z), \Pi(z), P(z)\} \cdot \exp[i(k_1 x_1 + k_2 x_2 - \omega t)] \quad (3)
\end{aligned}$$

Substituting (2) with (3) and cancelling out  $U_1$ ,  $U_2$ ,  $\Pi$  and  $P$  after proper manipulations, an equation for  $U_3(z)$  is obtained:

$$\begin{aligned}
U_3' - \left[ \frac{i 2 f_1 f_2 k_2}{\omega^2 - f_1^2} + \frac{N^2}{g} + \frac{g}{c_s^2} \right] U_3 + \frac{1}{(\omega^2 - f_1^2)^2} \left[ f_1^2 k_2^2 + (k_1^2 + k_2^2)(N^2 - \omega^2) - \right. \\
\left. - \omega f_2 k_1 \left( \frac{N^2}{g} - \frac{g}{c_s^2} \right) + \omega^2 (\omega^2 - f_1^2 - f_2^2) \frac{1}{c_s^2} + i f_1 f_2 k_2 \left( \frac{N^2}{g} + \frac{g}{c_s^2} \right) \right] U_3 = 0 \quad (4)
\end{aligned}$$

In order to eliminate those terms containing  $U_3'$ , let

$$U_3 = W(z) \Phi(z) \quad (5)$$

where

$$\Phi(z) = \exp \left[ \frac{1}{2} \int \left( \frac{N^2}{g} + \frac{g}{c_s^2} + i \frac{2 f_1 f_2 k_2}{\omega^2 - f_1^2} \right) dz \right] \quad (6)$$

Thus, an equation for  $W(z)$  is obtained:

$$W'' + m^2 W = 0 \quad (7)$$

in which

$$\begin{aligned}
m^2 = & \left[ k^2 \frac{N^2 - \omega^2}{\omega^2 - f_1^2} + \frac{\omega^2 f_1^2 k_1^2}{(\omega^2 - f_1^2)^2} \right] + \left( \frac{N'}{N} - \frac{\omega f_2 k_1}{\omega^2 - f_1^2} - \frac{N^2}{4g} \right) \frac{N^2}{g} + \\
& + \left[ \frac{\omega^2 (\omega^2 - f_1^2 - f_2^2)}{\omega^2 - f_1^2} + \frac{\omega f_2 k_1 g}{\omega^2 - f_1^2} - \frac{N^2}{2} \right] \frac{1}{c_s^2} - \frac{1}{c_s^4} \frac{g^2}{4} \quad (8)
\end{aligned}$$

where  $k = \sqrt{k_1^2 + k_2^2}$ , is the horizontal wave number.

If the boundary conditions of a flat sea floor and a rigid, flat sea surface are adopted, then

$$m = \frac{j\pi}{d}$$

where  $d$  is the depth and  $j$  the indice of modeled state.

Take  $O(d) = 10^3$  m,

then for the lowest state internal wave with maximum energy

$$O(m^2) = 10^{-6} \text{ m}^{-2}$$

Since  $O(f_1) = O(f_2) = O(2\Omega) = 10^{-4} \text{ sec}^{-1}$

and let's further take

$$\begin{aligned} O(N) &= 10^{-3} \text{ sec}^{-1}, \\ O(\omega) &= O(N), \end{aligned}$$

and assume

$$O\left(k^2 \frac{N^2 - \omega^2}{\omega^2 - f_1^2}\right) = O(m^2) = 10^{-6} \text{ m}^{-2},$$

then

$$O(k^2) = 10^{-6} \text{ m}^{-2},$$

assume also that

$$O(k_1^2) = O(k_2^2) = O(k^2) = 10^{-6} \text{ m}^{-2},$$

then the order of magnitude of each term in  $m^2$  are as follows (dimension:  $\text{m}^{-2}$ ):

$$\begin{aligned} m^2 &= \left[ k^2 \frac{N^2 - \omega^2}{\omega^2 - f_1^2} + \frac{\omega^2 f_1^2 k_2^2}{(\omega^2 - f_1^2)^2} \right] + \left( \frac{N'}{N} - \frac{\omega f_2 k_1}{\omega^2 - f_1^2} - \frac{N^2}{g} \right) \frac{N^2}{g} + \\ 10^{-6} &= [ 10^{-6} + 10^{-8} ] + \left( \frac{N'}{N} - 10^{-4} - 10^{-7} \right) 10^{-7} + \\ &+ \left[ \frac{\omega^2 (\omega^2 - f_1^2 - f_2^2)}{\omega^2 - f_1^2} + \frac{\omega f_2 k_1 g}{\omega^2 - f_1^2} - \frac{N^2}{2} \right] \frac{1}{c_1^2} - \frac{1}{c_1^4} \frac{g^2}{4} \\ &+ [ 10^{-6} + 10^{-3} - 10^{-6} ] 10^{-6} - 10^{-10} \end{aligned}$$

Ignore the small, higher order quantities, then

$$m^2 = k^2 \frac{N^2 - \omega^2}{\omega^2 - f_1^2} + \frac{NN'}{g} \quad (9)$$

If  $O(N') < 10^{-2} \text{ sec}^{-1} \text{m}^{-1}$  (which is closer to reality in ocean), then the second term in above equation can be omitted and (9) regresses into an expression often seen for vertical wave number

$$m^2 = k^2 \frac{N^2 - \omega^2}{\omega^2 - f_1^2} \quad (10)$$

(8) and (9) are still valid when  $O(\omega) = O(f)$ .

In deep water often  $O(N) = O(f_1) = O(f_2) = 10^{-4} \text{ sec}^{-1}$ . If taking  $O(N') = O(N/d) = 10^{-7} \text{ m}^{-1} \text{sec}^{-1}$  (which is an overestimation for deep locations where  $N$  are small) and using the above-mentioned order of magnitude comparison method, then, for  $m^2$ , only the terms within the first brackets in (8) are in the order of  $10^{-6} \text{ m}^{-2}$  while all others are smaller. Therefore, (8) regresses into

$$m^2 = k^2 \frac{N^2 - \omega^2}{\omega^2 - f_1^2} + \frac{\omega^2 f_2^2 k_2^2}{(\omega^2 - f_1^2)^2} \quad (11)$$

And (7) is greatly simplified:

$$W'' + \left[ k^2 \frac{N^2 - \omega^2}{\omega^2 - f_1^2} + \frac{\omega^2 f_2^2 k_2^2}{(\omega^2 - f_1^2)^2} \right] \bar{W} = 0 \quad (12)$$

Now we go back to check the order of magnitude for  $\Phi(z)$ , it can be easily seen that the order of magnitude of the first two terms within the integral in (6) are smaller than the third term, so

$$\Phi(z) = \exp \left[ i \frac{f_1 f_2 k_2}{\omega^2 - f_1^2} z \right] \quad (13)$$

and

$$U_3(z) = W(z) \exp \left[ i \frac{f_1 f_2 k_2}{\omega^2 - f_1^2} z \right] \quad (14)$$

### 3. Discussions

In the fluid dynamic problems dealing with homogeneous density fluid, the effect of compressibility on the flow is expressed by the Mach number  $M$  (the ratio of fluid flow velocity to the sound velocity at the same location). With larger  $M$ 's, the terms containing  $M$  cannot be ignored when compared with other terms in the equation and the problem should be treated as compressible. On the other hand, when  $M$  is small, those terms containing  $M$  can be omitted and the motion of fluid can be treated as incompressible. Because the velocity of sea water motion caused by oceanic internal waves is far smaller than the sound velocity in water, the oceanic internal wave motion has to be incompressible according to the principle described above. However, except for shallow upper ocean layers, the effect of compressibility has to be considered in actual oceanic internal waves and is represented by the influence of compressibility on  $N$ .  $N$  is a physical property of a lamellar fluid in

equilibrium rather than a kinetic quantity and is independent of the velocity of fluid motion. Therefore, the effect of compressibility on it naturally cannot be judged by the magnitude of  $M$ . The significance of the effect of compressibility is determined by the extent temperature, salinity and other physical properties affect the density. At the sharp thermoclines of upper ocean layer, changes of temperature and salinity with depth are greater and they are probably important contributing factors to the density change with depth. In deep water, the changes of temperature and salinity with depth are small and the density change with depth is also small (as can be seen from Table 1). The small change of density is mainly due to compressibility.

Because the differential equations of internal wave motion have the same form under both compressible and incompressible conditions, the only difference between them lies in the expression for  $N$ . Therefore, in dealing with actual oceanic internal waves, correct results are obtained when one uses the internal wave equations derived under the assumption of incompressibility and the  $N$ 's in these equations are substituted with the measured values which are influenced by compressibility, although it is logically inconsistent. Through our efforts as presented in this article this inconsistency is eliminated.

Equations (1), (5) and (11)-(14) are obtained under conditions more consistent with those in deep water (low  $N$  value and constant entropy) and, therefore, it is reasonable to believe that they more accurately describe the rules of internal wave motion in deep water. Judged from the perspective of WKB-type approximation, they are no more complex than ordinary equations. In addition, the  $N$  values at great depth are nearly constant and that makes the problems easier to handle.

Kamenkovich and Kulakov (1977) have derived equations that correspond to (4) under the assumption of incompressibility (which naturally do not contain terms that reflect the effect of compressibility) and solved those equations along with discussions. Therefore, no solving these equations and detailed discussions are intended in this article. However, several points are worth mentioning: First, the  $f_2$  and  $k_2$  in (11) and (14) appear together. When  $k_2 = 0$ , i.e. no north component of wave number, even with a small  $N$ ,  $f_2$  will have no impact on  $W$  or  $U_3$ . Secondly, the change in the frequency range of internal wave is no longer  $f_1 < \omega < N$  but rather

$$\omega_2 < \omega < \omega_1,$$

where

$$\omega_{1,2}^2 = \frac{1}{2} \left\{ N^2 + f_1^2 + \left( f_2 \frac{k_2}{k} \right)^2 \pm \sqrt{ \left[ N^2 + f_1^2 + \left( f_2 \frac{k_2}{k} \right)^2 \right]^2 - 4N^2 f_1^2 } \right\}$$

When  $k_2 = 0$  or  $f_2 = 0$ , it reverts to  $\omega_1 = N$  and  $\omega_2 = f_1$ . Otherwise, they would be associated with the complex factor  $(f_2 k_2 / k)$ . This is a very significant result. It shows that, when  $N$  is very small, the upper and lower limits of internal wave frequency vary with the direction of horizontal propagation of internal wave. The results of LeBlond and Mysak (1978) did not reveal this feature. Thirdly, because  $U_3$ , as expressed in (14), contains

the wave factor  $\exp\left[i \frac{f_1 f_2 k_2}{\omega^2 - f_1^2} z\right]$ , even if  $W(z)$  (which decays exponentially with depth) of the zero state is obtained from (12),  $U_3(z)$  would still maintain the feature of waveform changing with depth  $z$ .

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PHYSICAL SCIENCES

WIND WAVES IN GULF OF BOHAI STUDIED

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"A Study of Wind Waves in the Gulf of Bohai"\*]

[Text] Abstract: The wind wave generated during the passing of a cold wave is one of the most dangerous waves in Bohai. Through the analysis of a continuous record of the wind waves during the passing of a cold wave in early November 1968, it is pointed out in this article that, during the period of strong northerly wind following the passing of a cold wave in winter or spring, the development and decay of the wind wave spectrum in the waters of the Gulf of Bohai are mainly dictated by wind speed. The changes in the shape and scale parameters of the wind wave spectrum are also discussed and their respective formulas given.

The wind wave generated during the passing of a cold wave is one of the most dangerous waves in Bohai. In recent years, many scientists have investigated such problems as the cause and distribution of Bohai's huge waves.<sup>1,2</sup> However, reports on the cold-wave-associated wind and wave have yet to appear. Based on the wind and wave data gathered during the passing of a cold wave, several aspects of the wind wave caused by the cold wave were studied and the correlation of the wind and wave is described in this article.

I. Features of Cold Wave Passages in the Gulf of Bohai

The passing of a cold wave is a process of the mighty cold air from Asia Minor or northern China invading south or southeast. In the process, strong wind accompanied by a drastic temperature drop occurs over a large area. Because the strength of cold air and the path its center travels vary, the strength of the wind and the extent of temperature drop also vary. By analyzing the

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historical weather information, it is found that, under the influence of a cold wave, winds on the scale of 8-9 can occur and the wind direction generally falls between NW and NE.

The cold wave of early November 1968, studied in this article, is a typical weather process of the type that a cold front is accompanied by a low pressure system. The wind direction over the Gulf of Bohai was between ENE and N with maximum wind speed reaching 18 m/sec.

## II. Wave Data

In this article, 20 sets of wind and wave data were collected (see Table 1). They came from the observation data gathered at a site 18 km east of Xingang, Tanggu ( $38^{\circ}53'N$ ,  $117^{\circ}51'E$ ) by a wave meter modified from an ultrasound echo ranging device. The wind elements were recorded with a hand-held wind speedometer at the top of an observation deck in the sea. The criteria for data selections were: (a) The wave was registered for greater than 15-minute period and there were no apparent change in wind direction and wind speed within half an hour before and after the registration; (b) the simultaneous observation data of the wind were present; (c) the calculated wave spectrum had a distinctive main peak and relatively small secondary peaks.

The calculations of wave spectrum were mainly done by correlation method with some by Fast Fourier Transformation (FFT). The scattering data sampling time intervals were 0.75 s for both methods and other parameters were presented in Table 2.

## III. Characteristics of the Development of Wind Wave Frequency Spectrum

Figure 1 shows the correlation of wind and wind wave during 5-10 November 1968. The correlation of wave development and decay with fetch, wind direction and wind speed can be seen from the changes with time of wind elements and wind wave spectrum peaks  $S(\omega_M)$  as shown in the figure. Because the Gulf of Bohai is a semi-closed bay circled by land on three sides with only east side open to the Bohai and the strong winds generated by cold wave are predominantly northeasterly or northerly, the resulting wind waves are fetch-limited waves. Therefore, fixed wind direction implies fixed fetch and the impact of fetch on wind waves is reflected by the changes of wind direction. It can be seen from Figure 1 that, with steady wind direction, the wind waves are not significantly affected by wind duration. Rather, they change with wind speed.

It is clear from Table 3 that, during the passing of a cold wave, the wind wave spectrum peak frequency ( $\omega_M$ ) varies within the range of 0.8-2.5 rad/s and the corresponding wind wave period  $T$  is between 2.5 to 7.8 s. This confirms that the wind waves within the waters of the Gulf of Bohai have a shorter period and higher frequency. The corresponding spectrum peak  $[S(\omega_M)]$  can reach a maximum of 0.5896  $m^2 \cdot s$ .

Table 1. Original Data

(1) (2) 资料 编号	(3) 观测日期(日)	(4) 观测时间 (时, 分)	(5) 风 向	(6) 风 速 (m/s)	(7) 风 区 (km)	(8) 水深(m)
1	5	06:36	SW	9.0	35	9.3
2	6	20:46	S	8.5	70	7.5
3	7	10:53	NE	8.5	39	8.4
4	7	11:30	NE	11.0	39	8.7
5	7	12:54	NE	15.0	39	9.8
6	7	14:45	ENE	18.0	78	11.4
7	7	15:45	ENE	16.0	78	11.4
8	7	17:05	ENE	14.0	78	11.2
9	7	18:05	ENE	13.0	78	10.5
10	7	19:05	ENE	12.0	78	9.9
11	7	20:05	ENE	10.0	78	9.3
12	8	07:00	N	12.0	33	10.0
13	8	09:42	N	12.0	33	9.2
14	8	11:35	N	13.0	33	7.8
15	8	12:35	N	11.0	33	8.7
16	8	15:30	NNE	15.0	42	9.8
17	9	08:37	N	16.0	33	8.7
18	9	10:50	N	13.0	33	7.4
19	9	17:13		12.0		8.5
20	10	07:20	NW	8.0	14	8.6

Key:

- |                               |                   |
|-------------------------------|-------------------|
| 1. Data                       | 5. Wind direction |
| 2. Number                     | 6. Wind speed     |
| 3. Observation date (day)     | 7. Fetch          |
| 4. Observation time (hr, min) | 8. Depth          |

Table 2. Parameters for the Calculation of Wave Spectrum

(1) (2) 方 法	(3) 资料采样个数	(4) 计算的谱值个数	(5) 自由度	(6) Nyquist 频率 (Hz)
(7) 相关法	1600	42	75.69	0.667
FFT method	1024	64	16.00	0.667

Key:

- |  |                       |
|--|-----------------------|
| 1. Method                              | 5. Degree of freedom  |
| 2. Item                                | 6. Nyquist frequency  |
| 3. Number of data samplings            | 7. Correlation method |
| 4. Number of calculated spectrum peaks |                       |

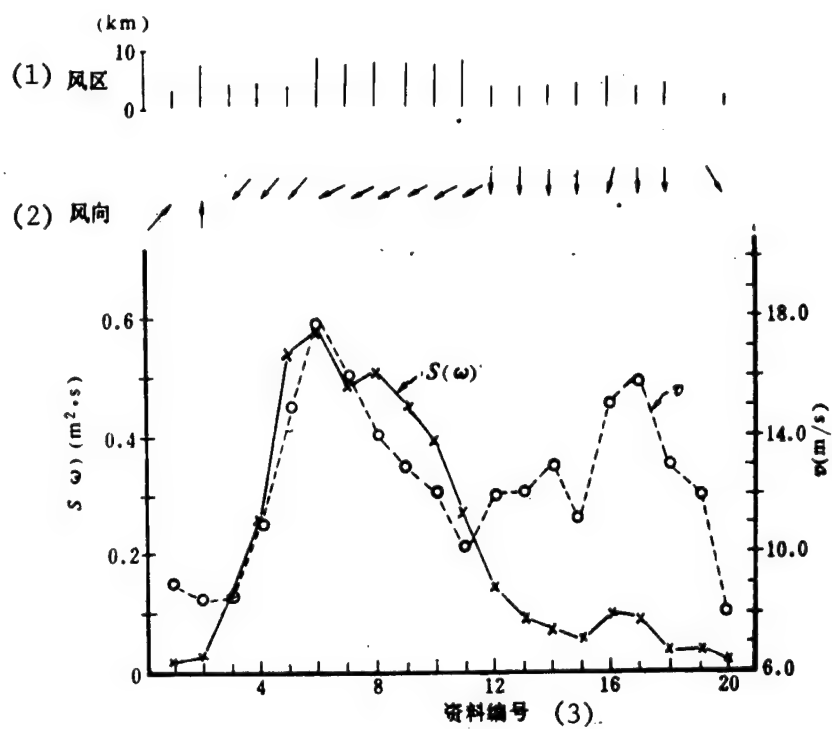


Figure 1. Correlation of Wind and Wind Wave  
 ---- Wind speed curve  
 — Time-dependence of spectrum peak

Key:

1. Fetch
2. Wind direction
3. Data number

Table 3. Spectral Parameters

(1) 资料编号	(2) 零阶矩	(3) 谱宽度		(4) 谱峰值 ( $m^2 \cdot s$ )	(5) 谱峰频率 (弧度/s)	(6) 无因次谱 峰频率	(7) 无因次风区	(8) 无因次能量
	$m_0$	$\delta$	$\nu$	$S(\omega_M)$	$\omega_M$	$\bar{f}_m$	$\bar{F}$	$\bar{E}$
1	0.0308	0.7805		0.0222	1.4	0.2044	$4.24 \times 10^3$	$9.03 \times 10^{-4}$
2	0.0252	0.7034		0.0288	1.4	0.1930	$9.50 \times 10^3$	$9.29 \times 10^{-4}$
3	0.0927	0.7224	0.1683	0.1257	1.4	0.1930	$5.30 \times 10^3$	$3.42 \times 10^{-3}$
4	0.1255	0.6623	0.3945	0.2572	1.4	0.2498	$3.16 \times 10^3$	$1.66 \times 10^{-3}$
5	0.2615	0.7319	0.1124	0.5422	1.2	0.2910	$1.70 \times 10^3$	$9.94 \times 10^{-4}$
6	0.4912	0.8191	0.7033	0.5869	0.9	0.2628	$2.36 \times 10^3$	$9.01 \times 10^{-4}$
7	0.3113	0.7618	0.5105	0.4877	0.9	0.2336	$2.99 \times 10^3$	$9.14 \times 10^{-4}$
8	0.4216	0.8523	0.6561	0.5163	0.9	0.2044	$3.90 \times 10^3$	$2.06 \times 10^{-3}$
9	0.2579	0.7808		0.4483	0.9	0.1823	$4.53 \times 10^3$	$1.74 \times 10^{-3}$
10	0.3038	0.8196	0.6575	0.3906	0.9	0.1752	$5.31 \times 10^3$	$2.82 \times 10^{-3}$
11	0.2250	0.7775	0.5228	0.2707	0.8	0.1298	$7.65 \times 10^3$	$4.34 \times 10^{-3}$
12	0.1088	0.6651		0.1463	1.4	0.2726	$2.25 \times 10^3$	$1.01 \times 10^{-3}$
13	0.0660	0.7486		0.0929	1.4	0.2718	$2.25 \times 10^3$	$6.13 \times 10^{-4}$
14	0.0587	0.7095		0.0758	1.6	0.3366	$1.92 \times 10^3$	$3.95 \times 10^{-4}$
15	0.1133	0.8240		0.0621	1.2	0.2141	$2.68 \times 10^3$	$1.49 \times 10^{-3}$
16	0.0701	0.7218		0.0985	1.5	0.3722	$1.83 \times 10^3$	$2.67 \times 10^{-4}$
17	0.0669	0.6959		0.0884	1.4	0.3634	$1.23 \times 10^3$	$1.96 \times 10^{-4}$
18	0.0404	0.6716		0.0360	1.5	0.3164	$1.86 \times 10^3$	$2.72 \times 10^{-4}$
19	0.0409	0.6577		0.0422	1.5	0.2920		$3.80 \times 10^{-4}$
20	0.0180	0.6556		0.0113	2.5	0.3245	$2.15 \times 10^3$	$8.46 \times 10^{-4}$

Key:

- |                      |                                    |
|----------------------|------------------------------------|
| 1. Data              | 5. Spectrum peak frequency (rad/s) |
| 2. Zero-order moment | 6. Non-dimensional peak frequency  |
| 3. Spectrum width    | 7. Non-dimensional fetch           |
| 4. Spectrum peak     | 8. Non-dimensional energy          |

Figure 2 is the spectrum density diagram showing the development and decay of wind waves from 10:53 to 19:10, 7 November. It can be seen from the graph that as the wind speed ( $v$ ) fluctuates, so does the spectrum density  $[S(\omega)]$ . At 10:53 of 7 November, the wind direction was ENE,  $v = 8.5$  m/s and  $S(\omega_M) = 0.1257$   $m^2 \cdot s$ ; at 14:50,  $v$  increased to 18 m/s and  $S(\omega_M)$  was also increased to 0.5869  $m^2 \cdot s$ ; and at 20:07,  $v$  decreased to 9.3 m/s and  $S(\omega_M)$  was decreased to 0.2707  $m^2 \cdot s$  accordingly. Also, the  $S(\omega)$  curves 3-6 in Figure 2 indicate the existence of "overshooting" phenomenon in the process of wind wave development. On curve 4,  $S(\omega_M) = 0.2573$   $m^2 \cdot s$  and  $\omega_M = 0.14$  rad/s. But on curve 5, which is 84 min later than curve 4,  $S(\omega_M)$  is only 0.1720  $m^2 \cdot s$  at the spectrum frequency of  $\omega = 0.14$  rad/s. This shows that when wind wave is growing with wind speed, the  $S(\omega_M)$  noticeably exceeds, at the corresponding frequency, those spectrum peaks observed during the later-stage development of the wind wave.

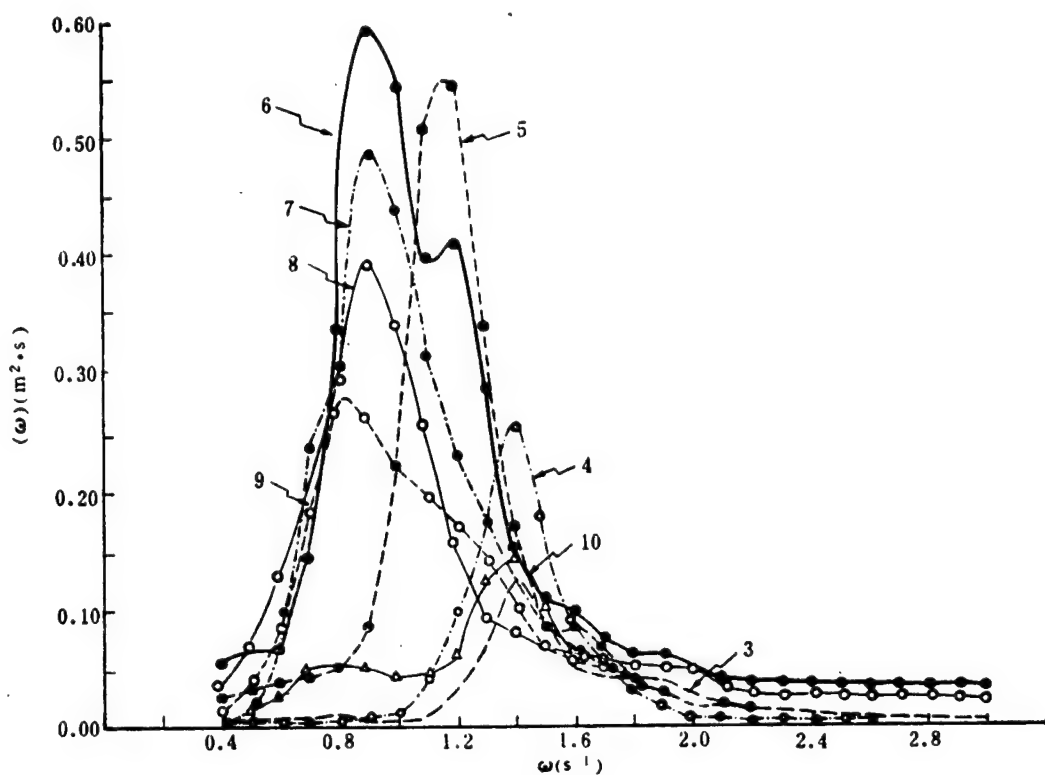


Figure 2. Spectral Density of Wind Waves

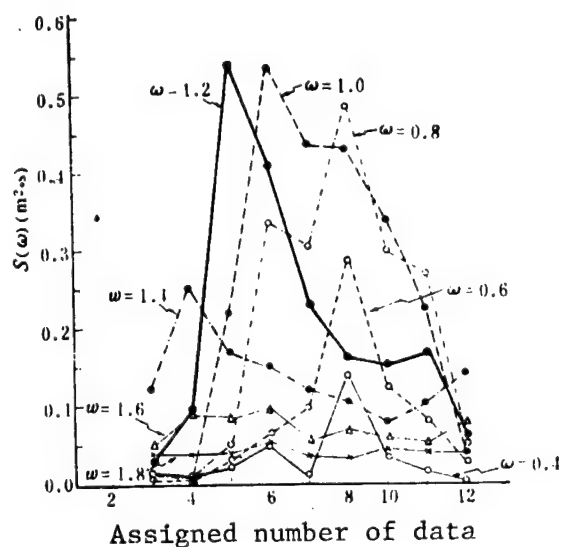


Figure 3. Time Variation of  $S(\omega)$

To observe more clearly the change of  $S(\omega)$  with time, a graph of  $S(\omega)$  versus time was drawn (see Figure 3), using wind wave frequency as a parameter. From the diagram, it can be seen that, when  $\omega > 1.5$  rad/s,  $S(\omega)$  changes very little

with time. And when  $\omega = 1.8$  rad/s,  $S(\omega)$  basically remains unchanged. This shows that all component waves reach the equilibrium range of the wave spectrum at the high frequency end.

#### IV. The Correlation of Wind Wave Spectrum Shape Parameters and the Spectrum

The  $n$ -th order moment of wave spectrum can be expressed as follows:

$$m_n = \int_0^{\infty} \omega^n S(\omega) d\omega \quad (1)$$

And there are generally two kinds of expressions for spectrum width:

$$\epsilon = \sqrt{1 - \left( \frac{m_2^2}{m_0 m_4} \right)} \quad (2)$$

$$\nu = \sqrt{\frac{m_0 m_2}{m_1^2} - 1} \quad (3)$$

where  $m_0$ ,  $m_1$ ,  $m_2$ ,  $m_4$  are the zero, 1st, 2nd and 4th-order moment of spectrum.

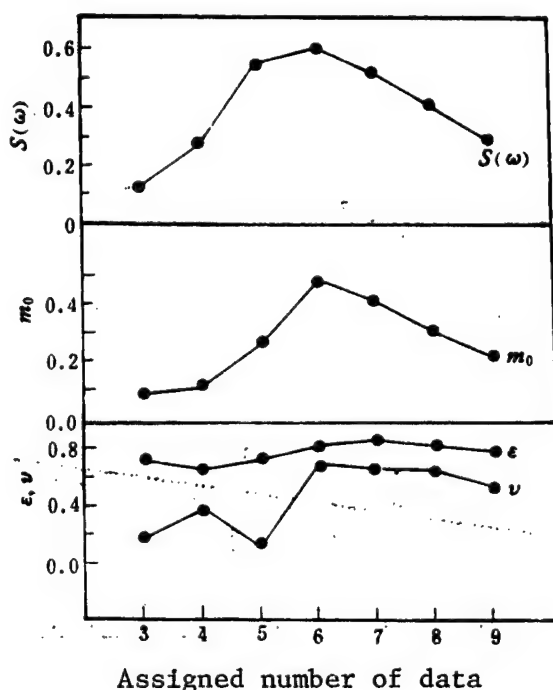


Figure 4. Time Variation of Spectrum Shape Parameters

Using the observed data and equations described above, the correlation of spectrum shape parameters and  $S(\omega_M)$  was obtained by calculations (as shown in Table 3 and Figure 4). The curves in Figure 4 clearly show that changes in  $M_n$ ,  $\epsilon$ , and  $\nu$  follow the same trend as that of  $S(\omega_M)$ . The fact that  $\epsilon$  fluctuates between a wider range ( $\epsilon = 0.6623-0.8523$ ) suggests that there are more high frequency components in the wind waves generated during the passing of a cold wave.

## V. Discussions of the Spectrum Scale Parameters

Based on the large collections of the observed data of North Sea, Hasselmann, et al.<sup>3</sup> proposed the JONSWAP spectrum to predict the waves of North Sea with satisfactory results. But it produced larger errors when used by Guang Yiheng [0342 2496 1854]<sup>4</sup> to predict the waves of Japan Sea. This suggests that the scale parameters of JONSWAP spectrum are area-specific. Guang Yiheng proposed a modification based on the observed data of Japan Sea. Using an approach similar to Guang Yiheng's and the observed data of the Gulf of Bohai, we will discuss the changes of the spectrum parameters of the fetch-limited wind waves generated during the passing of a cold wave. In order to make comparisons of numerical values in the discussion, all quantities are converted into their non-dimensional forms. The results are as follows:

### 1. Correlation of $\tilde{F}$ - $\tilde{f}_m$ and $\tilde{E}$ - $\tilde{f}_m$

The correlation of non-dimensional fetch ( $\tilde{F}$ ) and non-dimensional spectrum peak frequency ( $\tilde{f}_m$ ), and that of non-dimensional energy ( $\tilde{E}$ ) and  $\tilde{f}_m$  were calculated from the observed data and shown in Figures 5 and 6. The following relationships were derived by using least square method:

$$\tilde{f}_m = 3.51 \tilde{F}^{-1/3} \quad (4)$$

$$\tilde{f}_m \tilde{E} = 15.12 \times 10^{-4} \quad (5)$$

in which:

$$\tilde{F} = \frac{gF}{U^2}; \quad \tilde{f}_m = \frac{Uf_m}{g}; \quad \tilde{E} = \frac{gE}{U^4}$$

where  $F$  is fetch;  $U$  wind speed;  $E$  wave energy;  $f_m$  peak frequency ( $= \omega_M/2\pi$ ); and  $g$  acceleration due to gravity.

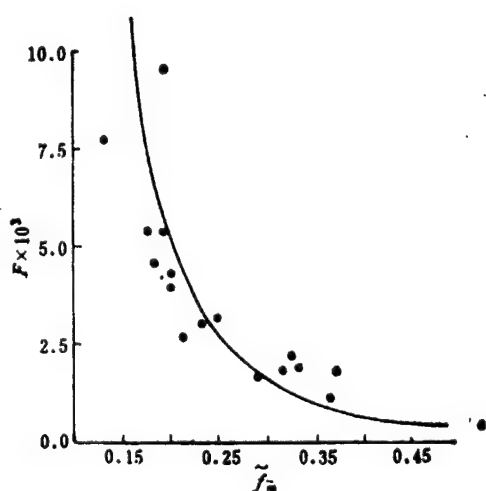


Figure 5. Correlation of  $\tilde{F}$  and  $\tilde{f}_m$

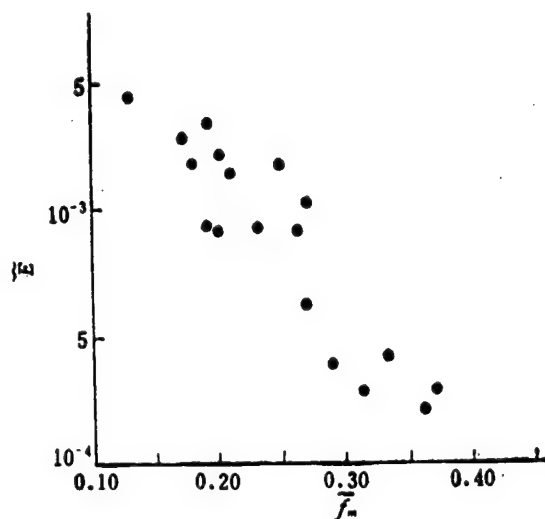


Figure 6. Correlation of  $\tilde{E}$  and  $\tilde{f}_m$

## 2. Correlations of $\alpha-\tilde{f}_m$ and $\gamma-\tilde{f}_m$

The expression for JONSWAP spectrum is:

$$S(\omega) = \alpha g^2 (2\pi) \omega^{-5} \exp \left[ -\frac{5}{4} \left( \frac{\omega_M}{\omega} \right)^4 \right] \gamma \exp \left[ -\frac{(\omega - \omega_M)^2}{2\sigma^2 \omega_M^2} \right] \quad (6)$$

in which the scale parameters  $\alpha$  and  $\gamma$  are calculated from the following equations:

$$\alpha = \frac{2}{\omega_M} g^{-2} \int_{1.5\omega_M}^{2\omega_M} \omega^5 \exp \left[ \frac{5}{4} \left( \frac{\omega_M}{\omega} \right)^4 \right] S(\omega) d\omega \quad (7)$$

$$\gamma = \alpha^{-1} g^{-2} \exp \left[ \frac{5}{4} \right] \omega_M S(\omega_M) \quad (8)$$

The integration interval of equation (7) is chosen when  $\gamma = 1$ , that is when the measured spectrum density  $S(\omega)$  reaches equilibrium, which means  $S(\omega)$  basically no longer changes with fetch and wind duration. Equation (8) is derived under the assumptions that  $\alpha$  values have been obtained from equation (7) and that  $\omega = \omega_M$ .

The correlation of  $\alpha$  and  $\tilde{f}_m$  and of  $\gamma$  and  $\tilde{f}_m$  (see Figures 7 and 8) as well as the following relationships can be obtained from the observed wind wave data and equations (7) and (8):

$$\alpha = 3.3 \times 10^{-2} \tilde{f}_m^{4/6} \quad (9)$$

$$\gamma = 4.5 \tilde{f}_m^{3/7} \quad (10)$$

The correlation curves of Hasselmann's and Guang Yiheng's, whose formulas are as follows, are also presented in Figures 7 and 8.

$$\left. \begin{array}{l} \alpha = 3.3 \times 10^{-2} \tilde{f}_m^{2/3} \\ \gamma = 3.3 \end{array} \right\} \text{Hasselmann} \quad (11)$$

$$\left. \begin{array}{l} \alpha = 3.26 \times 10^{-2} \tilde{f}_m^{6/7} \\ \gamma = 4.42 \tilde{f}_m^{3/7} \end{array} \right\} \text{Guang Yiheng} \quad (12)$$

It can be seen from Figures 7 and 8 that our correlation curve lies between those of Hasselmann's and Guang Yiheng's.



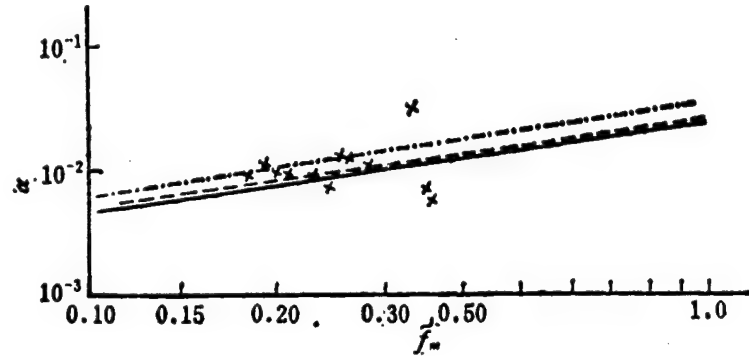


Figure 7. Correlation of  $\alpha$  and  $\tilde{f}_m$

..... Hasselmann; ----- Guang Yiheng; — the authors

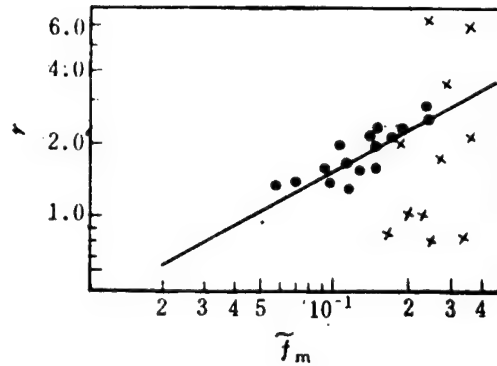


Figure 8. Correlation of  $\gamma$  and  $\tilde{f}_m$

● Guang Yiheng; x the authors

### 3. Correlation of $\alpha-\tilde{F}$ and $\gamma-\tilde{F}$

Based on the observed data, the correlation of  $\alpha$  and  $\tilde{F}$  and of  $\gamma$  and  $\tilde{F}$  were plotted (see Figures 9 and 10). The measured data of Hasselmann's and Guang Yiheng's were also included in the figures. Restrained by the topographical features of the Gulf of Bohai, the fetch measured is smaller ( $\tilde{F} < 10^4$ ) and therefore the measured values are concentrated in a small area in the graph. Substituting equation (4) into equations (9) and (10), respectively, and the following are obtained:

$$\alpha = 9.01 \times 10^{-2} \tilde{F}^{-4/5} \quad (11)$$

$$\gamma = 7.71 \times 10 \tilde{F}^{1/7} \quad (12)$$

It can be seen from Figures 9 and 10 that observed values agree better with equations (11) and (12).

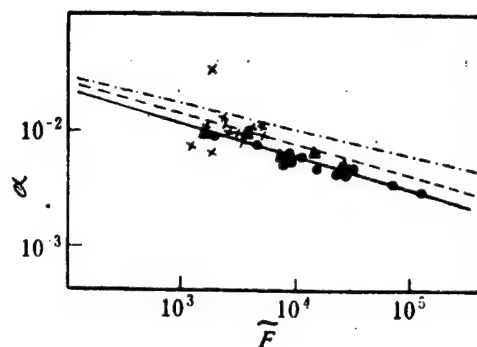


Figure 9. Correlation of  $\alpha$  and  $\tilde{F}$

▲ Hasselmann; ● Guang Yiheng; x the authors

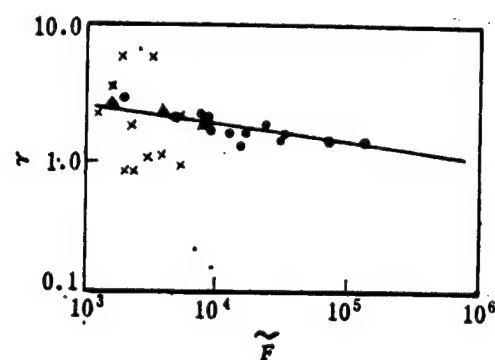


Figure 10. Correlation of  $\gamma$  and  $\tilde{F}$

▲ Hasselmann; ● Guang Yiheng; x the authors

## VI. Summary

1. During the passing of a cold wave, the waves of the Gulf of Bohai are fetch-limited. The impact of wind duration is insignificant. When a cold wave is moving south, wind speed rises and falls rapidly. Hence, the development and decay of wind waves coincide with the changes in wind speed.
2. The range of spectrum peak frequency of the cold wave generated wind waves,  $\omega_M$ , is 0.8-2.5 rad/s and the maximum spectrum peak generally is no greater than  $0.6 \times 10^4 \text{ m}^2 \cdot \text{s}$ .
3. The spectrum width is greater with a maximum of 0.85. This suggests that there is a wider distribution of bands and that the wind waves generated by cold wave consist of not only low-frequency waves but also a large number of high-frequency ones.
4. The distribution of the spectrum scale parameters of the wind waves generated by cold wave in the Gulf of Bohai agrees better with that from Guang Yiheng's equations.

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CSO: 4008/1068

LIFE SCIENCES

ACUTE LYMPHOBLASTIC LEUKEMIA, HLA

Beijing ZHONGHUA NEIKE ZAZHI [CHINESE JOURNAL OF INTERNAL MEDICINE] in Chinese  
Vol 25 No 4, 20 Apr 86 pp 217-219, 253-254

[English abstract of article by Qian Fengwei [6929 7364 0251], Ye Genyao [0673 2704 5069], Kong Fanhua [1313 4907 5478], Zeng Haiqun [2582 3189 5028], et al., of the 307 Hospital of the PLA]

[Text] The HLA-A, B, C antigens in 25 patients suffering from acute lymphoblastic leukemia (ALL) were compared with those of 78 normal healthy individuals in Beijing, while the HLA-DR antigens in ALL patients were compared with those in 74 normals.

The results showed that the phenotypic frequency antigens, i.e., Aw26 and Cw5 were increased in the ALL group, but only Cw5 was significantly increased in the ALL patient group ( $p = 0.0133, 0.05$ ) when the Fisher's P value was corrected.

Our results suggested that it appears there is an HLA-Cw antigen which might be associated with ALL in the Chinese population. (Paper received 24 April 1985, finalized 27 September 1985.)

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## ENVIRONMENTAL QUALITY

### WAYS TO REDUCE POLLUTION FROM BURNING COAL DETAILED

Beijing MEITAN KEXUE JISHU [COAL SCIENCE AND TECHNOLOGY] in Chinese Jul 85  
pp 28-30

[Article by Zhuang Yahui [8369 0068 6540], Mao Wenyong [3029 2429 3057], and Liu Shuangjin [0491 7175 6651], of the Chinese Academy of Science Environmental Chemistry Institute: "The Effects of Coal Processing and Utilization on the Environment"]

[Text] Coal is China's primary energy resource, accounting for over 70 percent of our energy consumption. According to statistics, by the end of this century coal will make up no less than 75 percent of all our energy resources.

Right now, China's methods of utilizing coal energy are behind the times. Medium and small coal-burning facilities predominate: we have 200,000 boilers nationwide that have a capacity of less than 35 tons of steam, and 70 percent of these have a capacity of less than 4 tons. The majority of our medium and small boilers and most of the coal stoves people use burn raw coal directly, have short chimneys, and are low in thermal efficiency. In addition, they lack ash-handling and desulfurization equipment, so coal combustion gives rise to severe pollution. In particular, household coal use in urban areas, though it accounts for only 20 percent of total urban coal consumption, is responsible for more than half of the sulfur dioxide pollution in each city. Therefore, the major research problems China faces in controlling atmospheric pollution are to develop new coal utilization techniques and to solve the problem of pollution caused by coal combustion.

This article attempts a brief commentary on economically feasible technological measures that can improve efficiency in coal use and aid environmental protection.

#### I. Molded Coal

Coal-fired installations in China are typically small and dispersed. In terms of investment, operating costs, and technical management, it will be very difficult to install perfect ash-handling and desulfurization equipment installation by installation. Consequently, the adoption of fuel control measures and the development of molded-coal processing are proven, effective measures.

By substituting molded coal for raw coal for use in boilers, kilns, and steam locomotives, 10 to 15 percent can generally be saved on coal and the volume of particulates and sulfur dioxide discharged can be distinctly reduced. Based on China's experience, although using molded coal is less environmentally beneficial than employing coal gasification or liquefaction, a comprehensive evaluation of environmental, energy-saving, and economic factors shows that it is still the fastest and cheapest way of controlling atmospheric pollution caused by coal combustion. The environmental benefits of coal processing are charted below:

Table 1. The Environmental Benefits of Coal Processing

Coal Processing Technique	% Reduction in Particulate Discharge	% Reduction in Sulfur Dioxide Discharge
Raw coal combustion	0	0
Coal dressing	0	50
Coal molding	30-60	30-60
Gasification	95	95
Fluidized-bed combustion	-	95
Coal slurry	-	90
Smoke and vapor desulfurization	-	85-95

Table 2. An Evaluation of Molded Coal Investment Benefits

Annual molded coal volume	6 million tons
Investment	3.4 million yuan
Unit price	51 yuan/ton
Reduction in particulate discharge	30 percent
Reduction in sulfur dioxide discharge	30 percent
Volume of coal saved per year	.8 million tons

In terms of molded coal for industrial and household use in China, there are now 18 kinds of molded coal for use in boilers, kilns, and household cooking and heating; 12 kinds of bonded coal are officially in use, including natural products and industrial products; 3 kinds of standardized molded-coal processing equipment have been put into use; and some corresponding furnace implements for molded coal have been developed.

## II. Fluidized-bed Combustion

Coal mines in China remove 60 to 70 million tons of waste rock each year, and coal washing plants also discharge 20 to 30 million tons of waste rock. Nationwide, over 1 billion tons of waste rock have been accumulated over the years--waste rock that has a calorific value of 1,000 to 2,000 kcal/kg. If this huge volume of mining waste is not disposed of appropriately it may give rise to pollution through spontaneous combustion or leaching.

This kind of low caloric fuel can be burned using fluidized bed combustion.

The development of fluidized-bed combustion in China is based primarily on the following considerations:

1. Various fuels that have a high ash content, high water content, low caloric value, or low volatility, such as oil shale, coal gangue, inferior coal, lignite, combustible slag, and so forth, can be burned using fluidized bed combustion. Most of the fluidized beds currently in use in China burn inferior coal. Bone coal from southern China has a high ash content and a low calorific value. Using ordinary means of combustion it is very difficult to burn and produces severe pollution, but this abundant resource can be utilized by employing fluidized beds. Fluidized beds are also particularly suitable for use in pithead power plants that burn coal gangue or washed coal.

2. In a fluidized bed, sulfur can be removed during combustion and abundant, inexpensive lime can be used as a desulfurizing agent. In addition, a fluidized bed burns at a low temperature, which is helpful in reducing the volume of hydroxides [as published] discharged. Southwest China produces a great deal of high-sulfur coal and possesses acidic soil, so acid rain poses a serious threat. In that area fluidization is an environmentally beneficial coal-use technique that provides an option.

3. The price of fluidized beds fluctuates little with the scale of the undertaking, and this is favorable for small-scale combustion. In China small-scale, dispersed industrial boilers and kilns account for approximately half of all the coal consumed, and this dispersion increases administrative problems. The development of fluidized beds is helpful in resolving pollution problems associated with the small-scale dispersed boilers that are still widespread in China.

4. The investment required for fluidized beds is relatively low, making them suitable for development in China. Fluid beds may increase combustion efficiency; they are a combustion method that makes coal burning more economical.

Operating costs have been calculated for representative fluidized-bed boilers. Their economic and environmental benefits are listed below:

Table 3. Fluid Bed Costs for Boilers Burning 10 t/h of Coal

Coal cost	450,000 yuan/year
Lime cost	88,000 yuan/year
Water and electricity costs	80,000 yuan/year
Depreciation and administrative costs	610,000 yuan/year
Reduction in sulfur dioxide	96 percent
Capital investment	380,000 yuan

Note: Caloric value is 4,000 kcal/kg; sulfur content is 3 percent; sulfur dioxide concentration at entry is 2,000 ppm; sulfur dioxide concentration at exit is 750 ppm.

### III. Routine Smoke Desulfurization at Coal-fired Power Stations

About one-fifth of the sulfur dioxide now discharged annually into the atmosphere in China comes from thermal power plants. According to statistics,

by the end of the century thermal power plants may use more than 300 million tons of coal, and the average sulfur content of the raw coal used will rise from the current 1.4 percent to 2 percent. Thus, annual sulfur dioxide emissions may exceed 8 million tons, leading to environmental pressures that cannot be ignored.

Right now, due to the high sulfur content of coal and the inability of coal washing to meet thermal power plant requirements for raw coal desulfurization, in some areas of China smoke emissions seriously exceed standards and, as a consequence, construction of certain power plants has been restricted.

China's flue desulfurization system for coal-fired power plants is still in various stages of development. From the lab it will enter immediately into intermediate trials or full-scale equipment testing. As yet there is no example of industrial application of this system. Some tests have indicated that installing smoke desulfurization equipment at power plants burning high sulfur coal offers distinct environmental and social benefits.

Because thermal power plant smoke desulfurization calls for a fairly high investment, entails high costs, and requires difficult, composite technology, our policy is to explore further, based on our own trials, the environmental and economic benefits and then build demonstrator industrial installations. Right now we are conducting selective comparisons on three technologies: a dry spray absorption method, a limestone wet washing method, and an ammonium phosphate fertilizer method. A preliminary economic analysis of smoke and vapor desulfurization conducted on a typical 25,000 kW unit follows:

Table 4. An Economic Comparison of 3 FGD [Flue-gas Desulfurization] Methods

Method	Dry Spray Absorption	Limestone Wet Scrubbing	Compound Ammonium Phosphate Fertilizer
Investment (yuan)	960,000	1,920,000	4,500,000
Absorbent cost (yuan/year)	576,000	158,000	277,000
Water, electricity costs (yuan/year)	43,500	310,000	206,000
Depreciation cost (yuan/year)	48,000	96,000	225,000
Operator labor cost (yuan/year)	42,000	144,000	12,000
Maintenance, management costs (yuan/year)	8,000	17,000	17,500
Recovered in by-product sales (yuan/year)	discarded	discarded	1,684,000

Note: Calculated based on a 25,000 kW capacity; rate of sulfur dioxide elimination is 85 percent.

When costs of dust collection and design are not included, these three methods are basically economical to the same degree.



#### IV. Washing

Coal washing brings multiple benefits, including desulfurization, reduction in ash content, and improvement in coal quality. These are not only economically beneficial, they also favor environmental protection. At present only a small proportion of coal in China is washed, in some provinces and autonomous regions less than 10 percent. Nationwide, due to the lack of coal washing and by-product recovery, the major collieries annually add to waste rock and coal ash by 70 million tons and 100 million tons, respectively. The 20 million tons of smoke particulates and 12 million tons of sulfur dioxide create heavy losses. For example, in Henan 44 million tons of coal were consumed in 1978, and over 90 percent of this was raw, unwashed coal. By comparison with the thermal energy utilization ratio produced by washed coal, a total of 12 million-plus tons of coal was wasted provincewide and 8 million tons of coal ash, 1.3 million tons of smoke particulates, and 1.2 million tons of sulfur dioxide were produced. Thus, the quantity of coal ineffectively transported was increased by 6 million tons, and accumulated economic losses reached to over 100 million yuan.

China currently produces about 100 million tons of high-sulfur coal (over 2 percent sulfur content) per year, and southwestern coal, in particular, is largely high-sulfur coal. Due to the lack of coal washing sulfur dioxide pollution is severe and the area has become a major acid rain region, corroding construction materials and endangering agricultural production.

As described above, China's energy-using installations are typically small and dispersed, so controlling fuel sulfur content is the preferred desulfurization measure. Based on preliminary calculations, to build a washing plant capable of handling 1 million tons of high-sulfur coal per year, if we figure a 20 yuan investment for each ton of coal we will need to invest 20 million yuan. Add in pyrite sulfur recovery equipment, and we will need another 3 million yuan. This kind of sulfur recovery unit can annually produce 20,000 to 30,000 tons of sulfur concentrate, worth 1.3 to 2 million yuan, and raise economic results by 1 to 1.7 million yuan. Thus, it is economically feasible and can also increase China's sulfur resources.

Coal washing is one major measure widely adopted by various nations to protect their environments, and it is also practical on a wide scale in China. However, due to economic and technical limitations, it is still difficult to implement in a comprehensive fashion. In the near future we should first pursue high-sulfur coal washing, develop a rational technique for utilizing washed gangue, recover sulfur resources from coal, and prevent pollution from gangue washing.

#### V. Coal Slurry

Relevant work on slurry combustion is still in the research and development phase in China. It is advantageous to use fuel oil as an industrial chemical or an export, and it will partially replace coal as a basic fuel. In hydraulic coal mining and in the washing process, coal may partially become coal slurry. Consequently, there are bright prospects for this fuel in

industrial boilers, kilns, and power stations. Combustion tests China has conducted on coal slurry indicate that a mixed fuel slurry composed of 65 to 70 percent dry coal can burn in a stable fashion and reach over 95 percent carbon conversion.

The primary environmental impact is brought about by the discharge of particulates, sulfur dioxide, and nitrogen dioxide. We have conducted an analysis to compare flue gas from coal slurry combustion and from fuel oil combustion, using the same boiler. When coal slurry is substituted for petroleum, environmental concentrations of sulfur dioxide may be greatly increased. Testing indicates that dolomite and limestone additives must be used to ensure relatively efficient desulfurization.

Coal slurry combustion and fuel oil combustion in boilers have the following environmental effects:

Table 5. A Comparison of the Effects of Coal Slurry Combustion and Fuel Oil Combustion in Boilers

	Oil	Slurry No 1	Slurry No 2
Slurry coal concentration (%)	--	61.2	72.0
Flue CO <sub>2</sub> concentration (%)	7.6-8.7	13.2	7.1-12.0
Flue NO <sub>x</sub> concentration (ppm)	25-35	0.20	10
Flue SO <sub>2</sub> concentration (ppm)	70-125	--	160-350
Flue CO concentration (ppm)	280-480	--	500-3,000
Flue particulate density (g/Nm <sup>3</sup> )	0.65-1.29	3.43	--
Flue hydrocarbon density (ppm)	120-240	--	120

In the coal slurry combustion technique NO<sub>x</sub> can be reduced 12 percent due to the low temperature of the flames. The nitrogen content of the fuel and the state of combustion within the boiler both affect the discharge of NO<sub>x</sub>. Particulate discharge in slurry combustion is higher by one level of magnitude than that in fuel oil combustion. Thus, we must improve the efficiency of dust removal in existing equipment or manufacture new dust-removal equipment.

#### Conclusions:

1. The condition of Chinese coal resources and usage and the state of the environment in China are very complex. No specific technology or technique can completely resolve environmental problems caused by coal combustion. We should conduct a comprehensive analysis, weigh the advantages and disadvantages, and choose and apply suitable techniques.

2. The use of molded coal is a simple and effective means to quickly improve combustion efficiency and alleviate atmospheric pollution brought about by coal combustion. It is worthwhile to enhance research and dissemination of this method. Right now we should work particularly hard to study and disseminate low-pollutant molded coal processing and smokeless technology.

3. Techniques for washing and desulfurizing high-sulfur coal and recovering sulfur resources are of major economic and environmental significance in southern China. This sulfur dioxide control tactic should be given priority consideration; we are in urgent need of a technological breakthrough in this area.

4. Medium and small boilers in high-sulfur coal regions should switch to fluidized-bed combustion, solve problems that exist with fluidized-bed ash and cinder disposal and dust removal, and improve thermal efficiency. Use of fluidized beds can then expand into combustion of coal with a high calorific value. This is the primary way to handle the gravity of pollution from China's scattered small boilers.

5. In high-sulfur coal regions and in areas in which the meteorological and geographical conditions are not conducive to smoke and vapor diffusion, coal-fired power plants should install flue-gas desulfurization devices. In this comprehensive and intense endeavour, all domestic sectors must enhance cooperation and tackle key problems. We must also draw on the experiences of other nations and augment international exchange and cooperation.

12510

CSO: 4008/2108

Engineering Thermophysics

EQUATION OF STATE FOR MOLECULAR AGGREGATION (OR ASSOCIATION) (MODEL FOR AGGREGATED HARD SPHERICAL MOLECULES)

Beijing GONGCHENG REWULI XUEBAO [JOURNAL OF ENGINEERING THERMOPHYSICS]  
in Chinese Vol 7 No 2, May 86 pp 93-98

[English abstract of article by Tong Jingshan [4547 2529 1472], et al., of Qinghua University]

[Text] In this paper we propose the theory of molecular aggregation (or association) and apply it to improve some equations of state. To prove the correctness of this theory and effectiveness of the proposed improvement the saturated vapor volume data of 30 substances (including strongly polar and associated compounds, such as ammonia, water methanol, ethanol, acetic acid, etc.) were calculated and compared with experimental data. The calculated results show that the improved equations are fairly fitted to the experimental data and also that the molecular aggregation theory developed by the authors is correct.

TRANSONIC CASCADE FLOW SOLVED BY SHOCK-CAPTURE COMPUTATION FOLLOWED BY  
SEPARATE-REGION COMPUTATION WITH SHOCK FITTING

Beijing GONGCHENG REWULI XUEBAO [JOURNAL OF ENGINEERING THERMOPHYSICS]  
in Chinese Vol 7 No 2, May 86 pp 112-119

[English abstract of article by Wu Zhonghua [0702 0112 5478], et al., of the  
Institute of Engineering Thermophysics, Chinese Academy of Sciences]

[Text] A new method is presented in this paper to solve the transonic flow past a compressor cascade in which the effect of the inlet bow wave and passage shock is considered, with the flow downstream being either subsonic or transonic. The computation consists of two steps. In the first step, a shock capturing solution is obtained by the use of a potential equation or stream function. The passage shock position obtained by either one or the average of the two is used as the starting value in the second step. In the second step, separate algorithms are used, respectively, for the supersonic flow upstream of and the subsonic or transonic flow downstream of the passage shock. The passage shock is adjusted after each cycle of calculation until the Rankine-Hugoniot relationships are satisfied. The axial-velocity density ratio and the increase in entropy due to the viscous effect downstream of the passage shock are also considered in the second step.

Calculations are made for a typical double-circular-arc cascade at inlet Mach numbers varying from 1.03 to 1.34. The effects of the axial-velocity density ratio and entropy increase downstream of the passage shock are clearly shown. The pressure distribution around the blade profile calculated with proper values of the axial-velocity density ratio and entropy increase compares favorably with the experimental data.

APPROACH TO AEROTHERMODYNAMIC PERFORMANCE PREDICTION OF GAS TURBINES  
CONTAINING WET STEAM CONDENSATION

Beijing GONGCHENG REWULI XUEBAO [JOURNAL OF ENGINEERING THERMOPHYSICS]  
in Chinese Vol 7 No 2, May 86 pp 130-132

[English abstract of article by Ling Zhiguang [0407 1807 0342], et al., of  
the Institute of Engineering Thermophysics, Chinese Academy of Sciences; and  
Fei Yang [6316 2254] of the Institute of Silicates, Chinese Academy of Sciences]

[Text] After introducing the basic relationships and fundamental equations of  
gas turbines containing wet steam condensation, a simple method is suggested  
based on replacing the condensation and heat release process thermodynamically  
by an equivalent polytropic process such that the usual gas medium calculation  
program can be employed and performance prediction can easily be made. The  
calculated performance of such a turbo expander shows good agreement with  
tested results.

EXPERIMENTAL INVESTIGATION OF COMPOSITE COOLING ON LEADING EDGE REGION OF  
TURBINE BLADE

Beijing GONGCHENG REWULI XUEBAO [JOURNAL OF ENGINEERING THERMOPHYSICS]  
in Chinese Vol 7 No 2, May 86 pp 147-150

[English abstract of article by Ji Honghu [0679 3163 3275], et al., of Nanjing  
Aeronautical Institute]

[Text] A semi-cylinder with film holes is used to simulate the impingement  
and film cooling on the leading edge region of a turbine blade. It is found  
that the impingement cooling on the concave surface is enhanced with the  
existence of film holes, and the film cooling effectiveness is evidently  
increased with the laterally slanted film holes.

NUMERICAL SOLUTION OF FLOW FIELD OF SHORT-ANNUAL COMBUSTION CHAMBER

Beijing GONGCHENG REWULI XUEBAO [JOURNAL OF ENGINEERING THERMOPHYSICS]  
in Chinese Vol 7 No 2, May 86 pp 176-178

[English abstract of article by Xu Hang [1776 5887], et al., of Beijing  
Institute of Aeronautics and Astronautics]

[Text] The recirculating flow field of a short-annual combustion chamber has been studied. The body-fitting coordinate system and the "simple" method combined with a constant viscosity model have been employed to solve the Navier-Stokes equations in cases where a complicated curved boundary exists. The results could provide the theoretical reference for the design and improvement of the short-annual combustion chamber.

9717

CSO: 4009/83



## Nuclear Techniques

## THE TDCR METHOD FOR ACTIVITY STANDARDIZATION IN LIQUID SCINTILLATION COUNTING

Shanghai HE JISHU [NUCLEAR TECHNIQUES] in Chinese No 5, May 86 pp 1-7, 58

[English abstract of article by Lan Yunxia [5663 0060 7209], et al., of Shanghai Institute of Nuclear Research, Chinese Academy of Sciences]

[Text] A new method for radioactivity standardization in liquid scintillation counting is described. In the method a triple to double coincidence ratio was taken for a reference quantity of efficiency change and the coincidence counting was extrapolated to the value of TDCR = 1, thus possibly leading directly to an approximate value for the sample activity.

This paper describes the principle of the method, the efficiency calculation and the estimate of the uncertainty. The measured results for tritiated water coincide with the nominal value of the NBS standard within an uncertainty of  $\pm 0.63$  percent.

INVESTIGATION OF TUNGSTEN SILICIDE FORMED BY As ION BEAM MIXING WITH  
RUTHERFORD BACKSCATTERING

Shanghai HE JISHU [NUCLEAR TECHNIQUES] in Chinese No 5, May 86 pp 13-18, 12,  
58-59

[English abstract of article by Wang Zhonglie [3769 1813 3525], et al., of  
the Low Energy Nuclear Physics Institute, Beijing Normal University]

[Text] The conditions for forming tungsten silicide with As ion beam mixing have been studied by means of Rutherford backscattering. A comparison between sintering and ion beam mixing is made. The phases have been identified by X-ray diffraction. The results demonstrate that the refractory metal silicide may be formed at a reduced reaction temperature using the ion beam mixing technique. The effect of oxygen impurity on silicide formation is observed. Finally, the mechanism of the formation of the silicide by ion beam mixing is discussed.

DISCRIMINATING  $\alpha$  PARTICLES FROM PROTONS WITH SOLID STATE TRACK DETECTOR

Shanghai HE JISHU [NUCLEAR TECHNIQUES] in Chinese No 5, May 86 pp 24-26, 42, 59

[English abstract of article by Jin Weiguo [6855 5898 0948], et al., of Fudan University]

[Text] In this paper a comparison is made of the general properties of a Chinese-made cellulose nitrate and two kinds of cellulose acetate films with different thicknesses in discriminating  $\alpha$  particles from protons. The 140  $\mu\text{m}$  cellulose acetate film is selected as the solid state track detector used in nuclear lifetime measurement by the blocking effect.

MECHANISM OF ACOUSTIC EMISSION GENERATED BY HIGH ENERGY CHARGED PARTICLES  
IN LIQUIDS

Shanghai HE JISHU [NUCLEAR TECHNIQUES] in Chinese No 5, May 86 pp 41-42, 61

[English abstract of article by Liu Yongyue [0491 3057 6885] of the Institute  
of High Energy Physics, Chinese Academy of Sciences]

[Text] The origins of the inconsistencies in the experimental data are  
analyzed. An analytical method is proposed, and the acoustic generation  
mechanism in liquids is examined. The results are inconsistent with any  
significant contribution from either microbubble formation or molecular  
dissociation. The thermoacoustic mechanism is dominant.

9717

CSO: 4009/84

## Optics

### RAMAN SPECTRA AND SYMMETRY OF $\text{LiZnTa}_3\text{O}_9$ CRYSTAL

Shanghai GUANGXUE XUEBAO [ACTA OPTICA SINICA] in Chinese Vol 6 No 5, May 86  
pp 391-395

[English abstract of article by Lan Guoxiang [5663 0948 4382], et al., of  
the Department of Physics, Nankai University, Tianjin]

[Text] Raman spectra of  $\text{LiZnTa}_3\text{O}_9$  crystal have been obtained for the first  
time and compared with those of  $\text{LiTaO}_3$ . Forward-Raman scattering shows that  
there is no polariton dispersion in  $\text{LiZnTa}_3\text{O}_9$ , thus we can conclude that the  
symmetry of  $\text{LiZnTa}_3\text{O}_9$  crystal is the  $D_{3d}$  point group. Finally, Raman spectra  
of  $\text{LiZnTa}_3\text{O}_9$  are assigned and discussed.

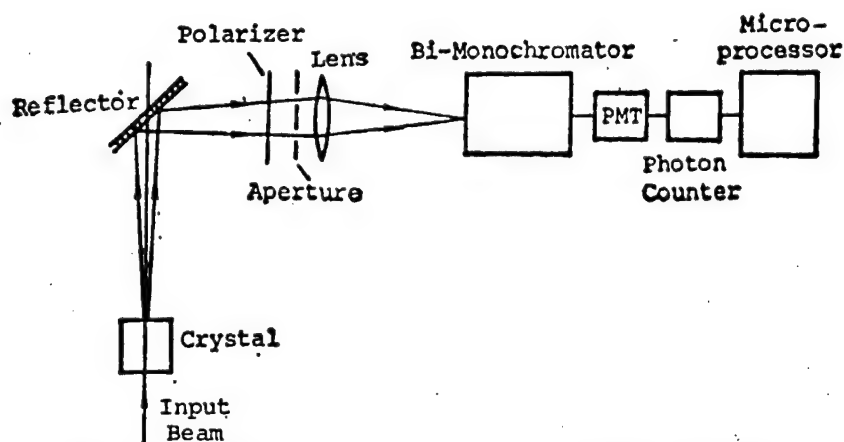


Fig. 1 Experimental arrangement for forward-Raman scattering

# OPTOGALVANIC SPECTROSCOPY IN Eu HOLLOW CATHODE DISCHARGE

Shanghai GUANGXUE XUEBAO [ACTA OPTICA SINICA] in Chinese Vol 6 No 5, May 86  
pp 396-401

[English abstract of article by Jing Chunyang [2529 2504 7122], et al., of the Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences]

[Text] A CW tunable dye laser was used to measure the optogalvanic spectroscopy of Eu. Sixty-five spectral lines were observed, 61 of which were from EuI and 4 from EuII.

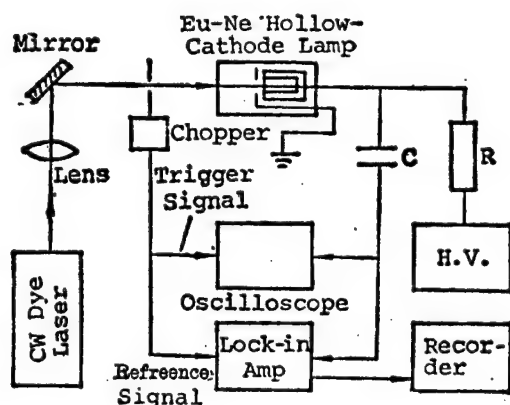


Fig. 1 Block diagram for measuring the optogalvanic spectroscopy of Eu

# HIGH EFFICIENCY FREQUENCY TRIPLING OF 1.06 $\mu\text{m}$ LASER RADIATION

Shanghai GUANGXUE XUEBAO [ACTA OPTICA SINICA] in Chinese Vol 6 No 5, May 86  
pp 413-419

[English abstract of article by You Chenhua [1429 2525 5478], et al., of the  
Department of Optical Instruments, Zhejiang University, Hangzhou]

[Text] In this paper coupled wave equations are solved for large signals by means of numerical integration. A numerical method for calculating SHG and THG efficiencies of beams with Gaussian temporal profiles is given. A high efficiency frequency tripling scheme for low and moderate power levels is presented. With type I  $\beta\text{-BaB}_2\text{O}_4$  crystal used in doubling and type II  $\text{KD}^*\text{P}$  used in tripling, energy conversion efficiencies of THG as high as 41.8 percent have been achieved at an energy level of 365 mJ.

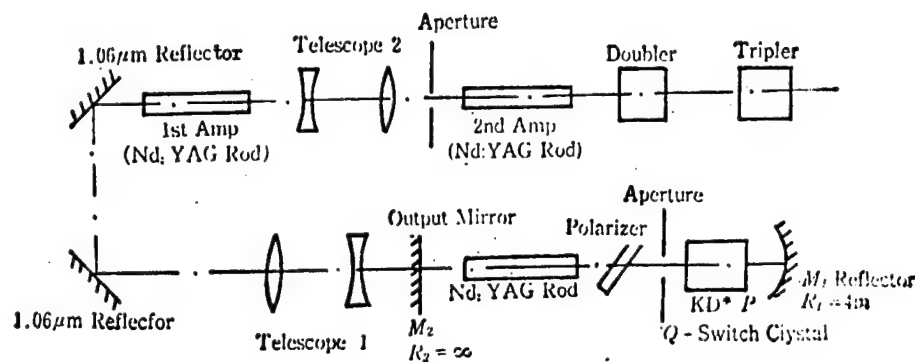


Fig. 7 Setup for THG experiment

# STUDIES ON MULTI-PHOTON OPTICAL BISTABILITY

Shanghai GUANGXUE XUEBAO [ACTA OPTICA SINICA] in Chinese Vol 6 No 5, May 86  
pp 427-432

[English abstract of article by Weng Zhaoheng [5040 0340 1854] of Changchun Institute of Optics and Fine Mechanics, Chinese Academy of Sciences; Ma Aiqun [7456 1947 5028], et al., of Harbin Institute of Technology]

[Text] In this paper a quantum mechanics model for describing multi-photon optical bistability is given. Based on this model, the state equation of multi-photon optical bistability is obtained. The method used for calculating the threshold of multi-photon optical bistability is also given. After analyzing the potential function, we obtain the static stability criterion and the explanation of switching characteristics. The stable region and inferior stable region in the bistability characteristic curve are separated. In fact, multi-photon optical stable states are actually multi-photon optical stable-inferior stable states. We also discuss the phase transition problem of multi-photon optical bistability and multi-photon lasers.



## WIDE ANGLE AND GREAT SCENE HOLOGRAPHY

Shanghai GUANGXUE XUEBAO [ACTA OPTICA SINICA] in Chinese Vol 6 No 5, May 86  
pp 433-439

[English abstract of article by Xing Liangling [1630 5328 2733], et al., of  
the Laser Research Institute, Suzhou University]

[Text] The present work is based on the teaching materials of experimental holography given by Professor J. Upatnieks and used at the Electrical and Computer Engineering Department, University of Michigan. After making some improvements in the optical system according to the experimental conditions in our institute, we succeeded in taking several wide angle and great scene holograms of Suzhou garden models (120 visual angle, 250 cm depth and 100 x 250 cm area), and obtained a bright and sharp three-dimensional reconstructed image. Therefore, this technique provides a cheap and practical method for taking holograms of great visual angle and scene in engineering structures, holographic displays, advertisements, artistic photography, data-storage, etc.

9717

CSO: 4009/85

Semiconductors

CARRIER TRANSPORT IN HETEROSTRUCTURE BASE REGION AND CARRIER CONFINEMENT  
FACTOR IN LASING REGION OF GaAs/GaAlAs PNP LASER

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7  
No 3, May 86 pp 227-236

[English abstract of article by Zhang Quansheng [1728 2938 3932] and Wu  
Ronghan [0702 2837 3352] of the Institute of Semiconductors, Chinese Academy  
of Sciences]

[Text] By solving the continuous equation, the carrier transport character-  
istics in the heterostructure base region of the transistor (DH laser struc-  
ture contained) in a GaAs/GaAlAs pnpn laser designed by the authors have been  
analyzed, with the carrier confinement factor in the lasing region given.  
(Paper received 6 March 1985.)

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CALCULATION OF SPREADING RESISTANCE CORRECTION FACTORS BY PIECEWISE  
QUADRATIC FUNCTION INTERPOLATION

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7  
No 3, May 86 pp 242-247

[English abstract of article by Shu Chang [5289 2545] and Bao Zongming [0545  
1350 2494] of Fudan University]

[Text] Piecewise quadratic function interpolation is proposed for the calculation of spreading resistance correction factors. The method is fast and highly accurate in calculations using a computer with small memory storage. It is very suitable for calculations by microcomputers. It takes 4 seconds to calculate a correction factor and less than 15 minutes to correct 35 data points on an Apple II in BASIC. (Paper received 20 March 1985.)

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## ELECTRONIC STRUCTURE OF $\alpha$ -Al<sub>2</sub>O<sub>3</sub>-Si INTERFACE

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7  
No 3, May 86 pp 248-253

[English abstract of article by Shen Qing [3088 3237], et al., of the  
Department of Physics, Sichuan University]

[Text] A DV-SCC-X<sub>α</sub> method is used to calculate the electronic structure of an  
 $\alpha$ -Al<sub>2</sub>O<sub>3</sub>-Si interface. The method, model and results are discussed. The  
results calculated, such as electric conductivity, energy gap and state  
density, are in good agreement with the experimental data. (Paper received  
27 March 1985.)

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# ADMITTANCE ANALYSIS OF DX CENTERS IN Te-DOPED LPE n-TYPE AlGaAs MATERIAL

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7  
No 3, May 86 pp 254-263

[English abstract of article by Ge Weikun [5514 1919 6924], et al., of the  
Institute of Semiconductors, Chinese Academy of Sciences]

[Text] We have measured the DX centers in LPE n-type  $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}:\text{Te}$  samples  
by both DLAS and DLTS techniques. Two energy levels which might be associated  
with the DX center were resolved:  $\Delta E_{\text{em}} = \sim 0.35 \text{ eV}$  and  $\sim 0.20 \text{ eV}$ ,  $\Delta E_{\text{eq}} =$   
 $\sim 0.10 \text{ eV}$  and  $\sim 36 \text{ meV}$ , respectively. (Paper received 8 April 1985.)

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FREQUENCY DEPENDENCE OF CAPACITANCE DERIVATIVES IN MOS CAPACITOR--NEW METHOD FOR DETERMINING THE DENSITIES AND CAPTURE CROSS SECTION OF SURFACE STATE AT Si-SiO<sub>2</sub> INTERFACE

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7 No 3, May 86 pp 264-274

[English abstract of article by Xu Mingzhen [6079 6900 4176], et al., of the Department of Computer Science and Technology, Beijing University]

[Text] The frequency dependence of capacitance derivatives in an MOS capacitor based on a single energy model and distributed energy model and the influence of random fluctuations of charge are discussed. The normalized analytic expressions are obtained. The densities, energy distribution and capture cross section of the surface state at the Si-SiO<sub>2</sub> interface may be determined simultaneously from the spectrum. This method has some advantages and is analogous to the conductance technique. The experimental results are consistent with the theoretical calculations. (Paper received 6 March 1985.)

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## CHANNEL ROUTING ALGORITHM USING HYBRID GRAPH

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7  
No 3, May 86 pp 292-297

[English abstract of article by Zhou Dian [0719 7193], et al., of the  
Department of Electrical Engineering, Fudan University]

[Text] This paper presents a hybrid graph model containing both directed and undirected edges for channel routing. Two algorithms have been established on the basis of this model. The algorithms take into account the global characteristics of constraints and develop a method which transforms the horizontal constraint into vertical ones, taking into consideration the relationship between the two kinds of constraints. In assigning a net segment to the track, the algorithms put an emphasis on the relativity of the net segment by putting off the earlier determination of the final position of the segments. In this case, the uncertainty in the assignment process can be avoided. The results calculated for some selected benchmark problems are the best yet determined. (Paper received 29 May 1985.)

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## METHOD FOR ELECTRICALLY ACTIVATING THE COPPER IN SILICON

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7  
No 3, May 86 pp 308-313

[English abstract of article by Chen Kaimao [7115 7030 5403] of the Department of Physics, Beijing University; and Qian Simin [6929 1835 2404], et al., of the Low Energy Institute, Beijing Normal University]

[Text] Only a very small proportion of copper in silicon is electrically active and, therefore, it cannot generally be detected. A method is suggested for activating the copper in silicon with electron irradiation and detecting it by DLTS. It is useful for detecting trace copper in silicon. A formula which can be used to estimate the average density of deep levels quite accurately is also suggested. (Paper received 6 March 1985.)

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# AUGER AND PHOTOELECTRON SPECTRUM STUDIES OF GaAs AND InP THIN ANODIC FILMS

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7  
No 3, May 86 pp 314-318

[English abstract of article by Zhou Mian [0719 0517], et al., of Shanghai  
Institute of Metallurgy, Chinese Academy of Sciences]

[Text] GaAs and InP thin anodic films with uniform thickness and good repeatability are obtained by using a newly developed solution of anhydrous tartaric acid and ethylene glycol, and analyzed by means of Auger and photoelectron spectra. It is found that the anodized GaAs films have uniform gallium and arsenic oxide, both at the surface and in the dielectric region, but excess As at the interface between the dielectric region and the semiconductor. For anodized InP films, the interface transition region is relatively narrow, and the excess phosphorus normally found is not observed. (Paper received 10 April 1985.)

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ELECTRON-BEAM RECRYSTALLIZATION OF RF SPUTTERING GaAs SOI AND THERMAL  
RECRYSTALLIZATION OF MBE GaAs SOI BY RF INDUCTION GRAPHITE STRIP HEATER

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[English abstract of article by Zhu Weiwen [2612 1983 7186], et al., of  
Shanghai Institute of Metallurgy, Chinese Academy of Sciences]

[Text] The electron-beam recrystallization of RF sputtering GaAs SOI and  
thermal recrystallization of MBE GaAs SOI by RF induction graphite strip  
heater are presented for the first time. Using ED, TEM, X-ray diffraction  
and the Hall effect, the grain size, crystal orientations, carrier concentra-  
tions and Hall mobilities of the GaAs films on SOI are measured. (Paper  
received 28 March 1985.)

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